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AN EXPERIMENTAL STUDY OF FIXATION OF RESPONSE BY COLLEGE STUDENTS IN A MULTIPLE-CHOICE SITUATION [1]

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Introduction.—In animal investigation the phenomenon of fixation was considered for a long time only as a curse which besets all rat runners since it usually prevents learning and so takes up time. However, following perusal of the clinical studies of Gelb and Goldstein, this behavior itself became the subject of investigation with the initial steps being taken by Hamilton and Ellis (**5**, **10**, **11**). In subsequent studies, especially those of Elliot (**4**), Hall (**9**) and Krechevsky (**13**, **14**, **15**), the shift in attitude from looking upon fixation as a special type of response to considering it as a measurable variable of behavior is most noteworthy. The writer, in this experiment, follows this trend of quantitative description by measuring fixation in terms of the proportion of different responses made of those possible; further, the use of human subjects extends the field of research on variability of response since this problem, in the sense used in animal experimentation, has received almost no attention in experimental human psychology.

In the problem used in the following studies, it was possible for subjects to discover choices that were correct part of the time. Improvement in performance past the point of making

[1] The writer is indebted to Dr. Warner Brown for his advice on experimental procedure and for his suggestions on the writing of this paper.

choices within a semi-correct spatial field was impossible. The experiments undertaken compare variability of response within this field by subjects working under different experimental conditions.

Experiment I

Subjects.—The subjects were seventy-five men and women members of elementary psychology classes in the University of California.

Apparatus.—The apparatus consisted of a forty key multiple-choice board. The keys were placed in line behind holes (1½ inches in diameter and 2 inches apart between centers) in a screen 32 inches above the floor. A strip of rubber dam, 6 inches wide, was fastened so that it covered all of the holes, and uniform vertical slits, 1½ inches long, were cut over each of the holes. An inch below each of the holes there was a thumb tack (called 'button' in the instructions). A curtain of black cloth was hung out from the top of the apparatus, 51 inches above the floor, so that it stayed slightly in front of the board down far enough to conceal the row of holes from a subject seated on the stool before the apparatus. Another black curtain was fastened at the bottom of the strip of rubber dam so that it hung down to the floor. The subject was able to locate each of the holes by the thumb tack below it. He could depress each key (which consisted of a metal strip) by putting a finger through the slit in the rubber dam in front of the hole. The keys were placed in circuit so that by pressing one a buzzer would sound if the experimenter had closed the corresponding key switch.

Procedure.—When a subject was seated on the stool facing the apparatus, the following written instructions were given to him:

Multiple Choice Problem

This is an experiment in problem-solving. The object of the experiment is to find how well you can solve a complicated problem.

You see before you a row of buttons. Above each of these there is a slit in a rubber surface which is concealed by a cloth hanging loosely in front of it. There is a key behind every slit, which can be pressed by putting your finger under the cloth above a button and through the corresponding slit. Some of the keys sound a buzzer, which means that the key is *correct On That Trial.* But the same key does not always sound the buzzer, because the problem is complicated.

You are to try to press the key which will sound the buzzer every time the experimenter says 'now.' The experimenter will indicate every time when you are to make a choice.

Note that you have to *remember* from trial to trial what you have done so that you can fit your partial solutions together in order to solve the whole complicated problem.

Try to make each choice right. The problem is solved when *Every Choice that You Make Is a Correct One.*

The illumination in the room was reduced. All of the subjects reported that the front of the apparatus was perfectly uniform and that there were no identifying marks on any part of it. The subject was then allowed to make 300 separate choices.

A group of adjacent keys made up the semi-correct field for any given subject. No choices outside of that area were ever correct. A master key was lifted by the experimenter on 75 of the 300 choices in a designed 'chance' pattern which allowed no more

than four nor less than two choices in the field to be correct in succession. The only solution that could be attained was to confine all the choices within the group of semi-correct keys, and at best not more than three fourths of a subject's choices would be correct.

Twenty-five different semi-correct fields were used and three subjects were tested on each one. These twenty-five fields represent the combinations of five different sizes of field and five different positions on the board. The sizes of fields used were ten keys, seven keys, five keys, four keys and three keys. Hereafter the size of a field will be represented by the number telling how many keys are included. The various positions of fields and the symbols representing them are: The extreme right end of the apparatus for the subject (*R*), an intermediate right position (*MR*), the center of the board (*C*), intermediate left (*ML*) and extreme left (*L*). Table 1 shows the keys included in each field. The numbering of keys is from the subject's right to his left, the key at his extreme right is number 1 and that at his extreme left number 40. This numbering was not known to the subject.

TABLE 1

KEYS INCLUDED IN THE SEMI-CORRECT FIELDS

Size of Field	Position in Line				
	Left	Middle Left	Center	Middle Right	Right
10 Keys.....	31–40	21–30	16–25	11–20	1–10
7 Keys.....	32–38	23–29	18–24	12–18	3–9
5 Keys.....	33–37	24–28	19–23	13–17	4–8
4 Keys.....	34–37	24–27	19–22	14–17	4–7
3 Keys.....	34–36	25–27	20–22	14–16	5–7

RESULTS

A. Learning the Semi-Correct Field.—Table 2 shows the progress of the subjects in confining choices within the semi-correct fields of various sizes and positions. The trials are combined in groups of 50 for this comparison. Although some of the sizes and positions differed rather widely from the general averages in the early groups of trials, by the fourth group of trials (151–200) all had at least 90 percent of the choices in the field. In the first 150 trials many of the subjects were making choices out of their field but in the second 150 trials very few of the choices were out of the field. The learning curve would show a plateau after trial 150. In all of the future analyses trials 1–150 and 151–300 will be dealt with separately.

B. Fixation.—In a rat experiment with a comparable set-up, Elliot (4) used two measures of fixation. One was the

TABLE 2

AVERAGE PERCENTAGE OF CHOICES MADE IN THE FIELD

Size of Field	Trials					
	1–50	51–100	101–150	151–200	201–250	251–300
10 Keys.....	56	80	85	94	92	94
7 Keys.....	49	77	93	96	93	94
5 Keys.....	44	80	90	90	93	93
4 Keys.....	46	78	84	90	92	94
3 Keys.....	35	75	93	97	98	98
Position of Field						
R.....	26	70	89	93	92	95
MR.....	57	85	86	93	95	95
C.....	65	88	95	95	95	95
ML.....	54	78	89	91	92	92
L.....	28	69	87	94	95	96
	Average of all Sizes and Positions					
	46	78	89	93	94	95

frequency of choices on the choice possibility which was used most often. The other involved treating the five alleys and the number of choices on them as a frequency distribution. The standard deviation of this distribution was taken as a measure of fixation. Hall (9) criticizes the first method because it considers just one of the alleys and therefore is not an accurate or valid measure. He also points out that the second method weights choices more heavily the farther spatially they are from the mean alley. This gives a very special meaning to the term fixation. Hall, in turn, used the standard deviation of the distribution of obtained frequencies around the chance frequency of an alley as his index of stereotypy. The formula is $\sqrt{\frac{\Sigma(\text{obtained-chance})^2}{\text{number of alleys}}}$. For a given number of trials and choice possibilities this index is satisfactory; however, since it varies directly with the number of trials and is not comparable for different numbers of possibilities, the writer feels that a more general index is desirable.

The last method described resembles the chi square function to some extent. It will be recalled that a formula for chi square is $\Sigma\left[\frac{(\text{observed-chance})^2}{\text{chance}}\right]$. This is used as a

measure of the agreement between an obtained and a chance distribution, the higher the value the less the agreement. In our experiment a high chi square secured in comparing the obtained distribution of choices in the semi-correct field with a chance distribution of choices (which would be obtained if all of the keys in the field were used equally) would indicate a high degree of fixation. It would mean that a few of the keys were used very often and the others were tried but infrequently.

This measure, as it stands, is open to the same objections as Hall's index. But in this case a remedy is possible. When the chi square value is put into the formula for the coefficient of contingency, $\sqrt{\frac{\chi^2}{N + \chi^2}}$, the effect of the number of trials is removed and when this quantity is divided by a correction for the number of choice possibilities,[2] a value is secured which is comparable for any number of trials or possible choices. This measure may be termed the Index of Fixation when applied in experiments comparable to the present one. It ranges in size from zero, which represents no fixation, to one, which represents complete fixation. In practice, the steps given above are not needed to find values for the index. The formula is given directly in crude frequency terms as:

$$\text{Fixation} = \frac{\sqrt{1 - \frac{(\Sigma X)^2}{t\Sigma X^2}}}{K},$$

where X indicates the frequency for a given choice possibility, t is the number of choice possibilities and K, the correction, is given by $\sqrt{\frac{t-1}{t}}$.

Table 3 shows the average fixation values for fields of various sizes and positions. The analysis of variance method

[2] Yule and Kendall (21) show that where t is the number of classes in a t by t contingency table, the highest value possible for the coefficient is $\sqrt{\frac{t-1}{t}}$. In the present use of the formula, where t is the number of reaction possibilities, the same limit exists. The above expression, then, gives the correction for the number of choice possibilities.

TABLE 3

FIXATION AVERAGES

Trials	Size of Field					Position in Line					Av.
	10	7	5	4	3	L	ML	C	MR	R	
1–150.....	.46	.49	.53	.49	.35	.49	.46	.44	.35	.59	.47
151–300.....	.52	.52	.52	.54	.50	.51	.50	.46	.50	.64	.52

as presented by Snedecor (**20**) was followed in order to see if the differences in the size or position of field resulted in differences in fixation. In trials 1–150 the greatest source of variation was found to be in the distance of the field from the center of the board, those farther out showing greater fixation. The ratio of the variance estimated on the basis of distance to the experimental error (in this case, the estimate of variance within the same size and position subclasses) which is 2.92 is not significantly different from chance. This ratio is the *F* value used by Snedecor. The variance estimated by the differences among fields the same distance from the center of the board and by differences in size of field could easily be due to chance. Likewise the interaction, 'the differential effects of variations in one factor in the presence of variations of another factor' (**2**) (in our case size and position), is not a significant source of variation. In trials 151–300 all of the differences are in the realm of chance. The very close agreement in the average amount of fixation of the various sizes of field is especially striking.

In comparing the average fixation of all of the subjects for trials 1–150 with that for trials 151–300 it was found that the latter was greater. The average for trials 1–150 is .47 and for trials 151–300 is .52. Fisher's *t* score (**7**) of this difference, 2.59, is significant since it is past his 5 percent criterion. The correlation between fixation scores for the first and second 150 trials was determined to be .72, a fairly high value.

DISCUSSION

The only differences in fixation which approach significance are between fields of different distances from the center

of the board during the first 150 trials. An examination of the responses of the subjects shows that this is explainable on the basis of their being seated on a stool which was near the middle of the apparatus, making keys near both extremes of the apparatus difficult for them to reach, and to their tendency to start exploration from the middle of the board and to work outward. Because of this, some of the subjects whose semi-correct field was peripheral never reached the most peripheral part of their field and thus obtained high fixation scores. The difference, even if it were significant, could well be attributed to these mechanical factors. The almost identical averages in fixation during the second 150 trials demonstrates that the index used would give comparable values for groups working under the same conditions with the exception of the number of choice possibilities. There is probably no real sense in arguing whether or not there was 'really' the same

TABLE 4

ANALYSIS OF VARIANCE OF FIXATION VALUES

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	*F*
Trials 1–150				
Total	74	3.92		
Within Fields (Error)	50	2.38	.048	
Between Fields of Different Size	4	.27	.068	1.42
Between Fields of Different Distance from the center	2	.28	.140	2.92
Between Fields of Equal Distance from the Center	2	.16	.080	1.67
Interaction (Field Discrepance)	16	.83	.052	1.08
Trials 151–300				
Total	74	5.17		
Within Fields of Equal Distance from the Center (Error)	72	5.02	.070	
Between Fields of Different Distance from the Center.	2	.15	.075	1.07

In trials 151–300, the differences in distance were the only sources of heterogeneity. None of the above *F* values are significant.

amount of fixation in the fields composed of different numbers of keys. From an operational point of view, the Index of Fixation indicates what is meant here by fixation. It suffices to say that in the present experiment it was found that the values given by the Index of Fixation did not depend upon the number of choice possibilities. Further, this was especially true during the last 150 trials when the subjects in fields of various sizes were comparable in their apprehension of the general solution, *i.e.*, the difference between the semi-correct field and the surrounding never-correct choice possibilities.

The fact that the average fixation for the last 150 trials was higher than that for the first 150 is no doubt due to the tendency of subjects to find all of the correct keys in the early part of their sessions and only in the later part to work intensively to find *the* solution. Regardless of this difference, the correlation of .72 between fixation scores in the two groups of trials indicates that the amount of fixation for any given subject tends to maintain a constant position in reference to the amount of fixation for the other subjects throughout the different stages of attempting to solve the problem.

Experiment 2

Subjects.—The subjects were forty men and women students. They were, for the most part, members of elementary psychology classes.

Apparatus.—The apparatus was identical with that used in Experiment 1 with the following exceptions:

The strip of rubber dam was removed from the front of the board. A ledge was formed in the bottom curtain just below the row of tacks. Two of the four groups in this experiment worked within a limited field instead of on all forty of the keys. Limiting the number of keys was accomplished by the use of two pieces of cardboard that extended out toward the subject. These were 7 inches high and 11 inches long. They were fastened to C-clamps which were attached to the ledge. Finally, instead of the stool, a low bench, 45 inches long, was placed in front of the apparatus.

Procedure.—The instructions were the same as those in Experiment 1 with the exception of the slight revision occasioned by the changes in the apparatus.

The same semi-correct field, composed of keys 11–20, was used for all of the subjects. The subjects were divided into four groups. The field in which groups A and B could work was limited by the cardboard boundary guards to keys 11–20. Groups C and D were allowed to use all forty of the keys. Subjects in groups B and D were blindfolded. The illumination for groups A and C was cut down as in Experiment 1. Members of the vision groups could locate the holes for the keys by the light reflected from the thumb tacks below them; the blindfolded groups' members could do so by running their forefingers over the ledge and thereby touching the thumb tacks. The

conditions for each of the four groups of ten subjects are shown below:

	Vision	Blindfolded
Boundaries	A	B
No boundaries	C	D

The procedure described in Experiment 1 was followed, each subject having 300 trials.

Results

A. Learning the Semi-Correct Field.—The only groups that can be compared in this respect are groups C and D since they alone had the possibility of making choices out of the semi-correct field. The criterion of learning was the percentage of choices made within the field during the second 150 trials. The average for group C was 92 percent and that for group D was 98 percent. This difference is significant as indicated by the *t* score of 2.88 which is past the 1 percent limit. The 'better' performance of group D can be accounted for only by the fact that members of this group were blindfolded while group C was allowed vision.

TABLE 5

FIXATION. EXPERIMENT 2

Averages

Group	Condition	Trials	
		1–150	151–300
A	Vision, Boundaries	.36	.37
B	No Vision, Boundaries	.51	.48
C	Vision, No Boundaries	.40	.44
D	No Vision, No Boundaries	.66	.74

t Scores

Difference	Trials	
	1–150	151–300
B–A	1.33	1.21
D–C	3.89 prob. of chance diff. less than .01	3.70 prob. of chance diff. less than .01
C–A	.44	.85
D–B	1.63	2.69 prob. of chance diff. less than .02

B. Fixation.—The Index of Fixation previously described was again used. Table 5 gives the average Index of Fixation

for each of the four groups for both the first and second 150 trials. The lower part of the table gives Fisher's *t* scores for the differences between the groups compared and indicates which of these differences are significant. The difference, in both sets of trials, between groups C and D is very significant. These were both no-boundary groups so the greater fixation in group D is attributable to the blindfolding of its members; however, in the groups with boundaries, A and B, the slightly greater fixation in the no-vision group B, is not significant. A significant difference is found in trials 151–300 when comparing the two blindfolded groups, B and D. Here the group without boundaries, D, showed more fixation. The differences between groups A and C, neither blindfolded, is far from significant. The presence of boundaries made no appreciable difference in this case.

Discussion

The 'better learning' of group D when compared with the other no-boundary group, C, can be attributed to the greater fixation of group D whose members were blindfolded. In this problem a great deal of variability of response was favorable to making choices out of the semi-correct field. As comparable examples of 'helpful handicaps,' cases in which animals with brain lesions showed better learning than normal animals could be cited (**17**).

An important difference between groups C and D, neither of which had boundaries, was that the former group, having vision, had superior ability to discriminate among the keys. The writer interprets the greater amount of fixation of group D on the basis of the lack of discriminability of the various keys for this group. Support for this interpretation is found in the comparison of the two blindfolded groups B and D. Here B had boundaries at either end of the semi-correct field by which each key could be located and, it will be noted, showed more variability than D. In contast to the above, in the two comparisons in which the situations were more nearly equally differentiable, between the two boundary groups A and B, and between the two vision groups A and C,

there were no significant differences in fixation. In this experiment, then, it was indicated that decreased differentiation (discrimination, identification, etc.) of choice possibilities may result in increased fixation.

Let us examine previous findings on conditions favorable to fixation to see if they are understandable on this basis. They may be listed under four principal rubrics:

First of all, there is the condition where the experimenter has set up a problem in which a discrimination is demanded and the experimentee counters with a position habit. No rat runner need be told of this situation. The position habit may be considered as a spatial fixation on the part of the subject to whom the differences in the choice possibilities are either indistinguishable or unnoticed. An example is found in Munn's experiment on color vision in rats (**18**). When rats were required to distinguish between a green and a yellow (which were of equal brightness for them) they developed position habits in the choice set-up. Under conditions of this sort the writer's findings that fixation may result from poor differentiation receive support.

Secondly, there is the condition of brain lesions. This can be considered as a case in which the animal is perennially faced with 'too difficult a discrimination' to respond to in all its complexity. Animal experimentation (**5**, **10**, **11**, **13**, **14**, **15**) and the clinical studies of Gelb and Goldstein agree that brain injury results in fixation of response.

While these first two main causes of fixation may be viewed as adding evidence in favor of the view presented in this paper, the next two conditions do not give any such support. Instead, the present hypothesis is given as a possible explanation of the way in which they operate.

Excessive practice, when accompanied by reward, is indicated as a condition which leads to fixation of response. Krechevsky and Honzik (**16**) report that rats, after learning to take a rewarded path in preference to a non-rewarded one, have difficulty in changing to the latter path when it is made the rewarded one. This difficulty was found to be in proportion to the frequency of choices they have made over the

former path. By postulating that this post-learning frequency removed the discriminal aspect from the situation or made discrimination more difficult this result can be explained in the terms followed thus far.

In the same way, the present experimental results may be an aid to understanding the fourth main condition leading to fixation, a state of stress. This category includes shock (3, 6, 12, 19), extreme hunger (4) and jump required (3). It is reasonable to suppose that these, in emphasizing an end, deëmphasize the means to that end in lessoning the examination of choice alternatives. Thus, as in the case of excessive practice, fixation is explainable as a result of the removal of the discrimination aspect from the situation. An experiment of Gilhousen (8) in which fixation appeared after forced runs over one of many possible paths demands further explanation. There have been experiments in which guidance was found to have little effect on subsequent behavior (1); so the specific apparatus used is of considerable importance. The paths, in the case under discussion, consisted of series of jumps. By extending the above reasoning it is possible to conclude that a jump set-up can be more easily changed than can a running set-up from a discrimination situation to one calling for an unvarying response on the part of the animal. It would be more justified to speak of fixation as a result of the interaction of the two factors of jump and forced path rather than as a result of one or the other.

Summary and Conclusions for Both Experiments

Subjects were given 300 choices on a multiple-choice board. For each subject there was a group of adjacent keys which were correct seventy-five percent of the time. None of the other keys were ever correct.

In Experiment 1 twenty-five different semi-correct fields were used, including five different positions on the board and five different sizes (numbers of keys). Within trials 151–200 at least ninety percent of the choices were made in all of the semi-correct field positions and sizes. An Index of Fixation was devised which gives a value of 1 when all of the choices

are on one key and goes down to 0 when the choices are scattered evenly over all of the reaction possibilities. The greater fixation average of trials 151–300 as compared to trials 1–150 is attributed to the general exploration of keys in the early trials. A correlation of .72 in fixation scores between the first and last 150 trials indicates that fixation is a constant for a subject relative to the group in this experiment. There were no significant effects on the amount of fixation which could be ascribed to differences in the position or size of the field.

In Experiment 2 there were four groups of subjects. Two groups were allowed vision, as in Experiment 1, and the other two groups were blindfolded. One of the vision groups and one of the blindfolded groups was given boundaries which confined them within the semi-correct field. This field included the same keys for all of the four groups. Significant differences were found in comparing the group without vision or boundaries with the group having vision but no boundaries and with the group having no vision but having boundaries. The greater fixation in the no-vision no-boundary subjects is attributed to their poorer discrimination among the keys. The greater number of choices within the field by this group when compared with the vision but no-boundary group is explained by the greater fixation of the former. It is suggested that the fixation found by other observers is explainable on the basis of lack of differentiation among choice possibilities on the part of the subjects.

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A STUDY OF PATTERNING IN THE CONDITIONED EYELID RESPONSE[1]

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INTRODUCTION

A description of the patterning of initial conditioned responses and subsequent shifts in these patterns derives its importance partly from the light it may throw on the relationship between the conditioned response and the unconditioned response. That this problem is by no means settled has been pointed out by Hilgard (6). Upton (14), Wever (16), Wendt (15), Schlosberg (13), and others have reported data indicating that the form of the conditioned response is not always the same as the form of the unconditioned response. The question in regard to the origin of this difference in form has not been answered, and a study of the shifts in pattern of a conditioned response may be expected to throw some light on the problem.

Hilgard (5) and Miller and Cole (10) reported some characteristic differences between the conditioned and unconditioned eyelid responses; and Bernstein (1) has classified patterns of conditioned eyelid responses, although he did not use his classification in further analysis of his data. Marquis and Porter (9) reported that conditioned responses based on voluntary eyelid closures could be differentiated from conditioned responses based on reflexly obtained eyelid closures by differences in the appearance of the eyelid patterns. It seems, however, that no study has been made of the qualitatively different patterns of a conditioned response and of the later shifts in these patterns during the conditioning series.

The problem undertaken in this study was to describe the different patterns of the conditioned eyelid response, and to

[1] This experiment was carried out at the State University of Iowa, and was written up at the University of Wisconsin. The writer wishes to thank Professor Halsey Cason for assistance in the preparation of the manuscript.

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investigate the changes in these patterns from their initial to their final appearance.

Procedure

The present study consists in an analysis of the patterns of conditioned eyelid responses which were obtained in a previously reported experiment (4). Since the procedure was described in some detail in the earlier paper, we shall give only a brief summary in the following paragraphs.

The unconditioned or original stimulus was provided by a puff of air delivered to the right eye. The conditioned or substitute stimulus was provided by an increase in the illumination of a small milk-glass window. The air-puff was given about .45 sec. after the beginning of the light stimulus, which remained on until after the eyelid reaction was completed.

The subjects were divided into two groups on the basis of two sets of instructions. In the *active* group, seven subjects were instructed to maintain an active, expectant, and attentive attitude toward the source of the light stimulus, and to respond to the onset of this light stimulus by tapping with the right index finger. The nine subjects in the *passive* group were instructed to adopt a completely passive and indifferent attitude toward the experiment, but to maintain their fixation on the disk where the light stimulus was presented.

Each subject came for four consecutive days. On the first day, records were made of unconditioned responses to the light and to the puff, and records were also made of the voluntary reaction-time response of the eyelid to light alone. No paired stimulation was given on the first day.

On both the second and third days, there were five presentations of light alone, then fifty of light followed by the air-puff, and finally five more presentations of the light alone.

On the fourth day, the light stimulus was given for 20 trials, except in the case of some subjects, where the light stimulus was given less than 20 times if the conditioned response failed to appear or extinguished quickly.

A modification of the Dodge pendulum photochronograph (3) was used to control the temporal relations of the stimuli and to record the movements of a small artificial eyelash attached to the eyelid. The response of the eyelid as recorded on the sensitized paper is subject to a certain amount of distortion as has been previously described (4), but in general the eyelid movement is faithfully reproduced.

Results on Unconditioned Responses

The patterning of the eyelid response with which we are concerned in the present study consists in the changes in the position of the eyelid as recorded by our photographic apparatus. Six records from the present study, which will be described in detail below, are presented in Fig. 1. The graph-like background is made up of curved concentric abscissæ which are 1.25 mm apart on the original records and straight ordinates which indicate .01 sec. time intervals. The passage

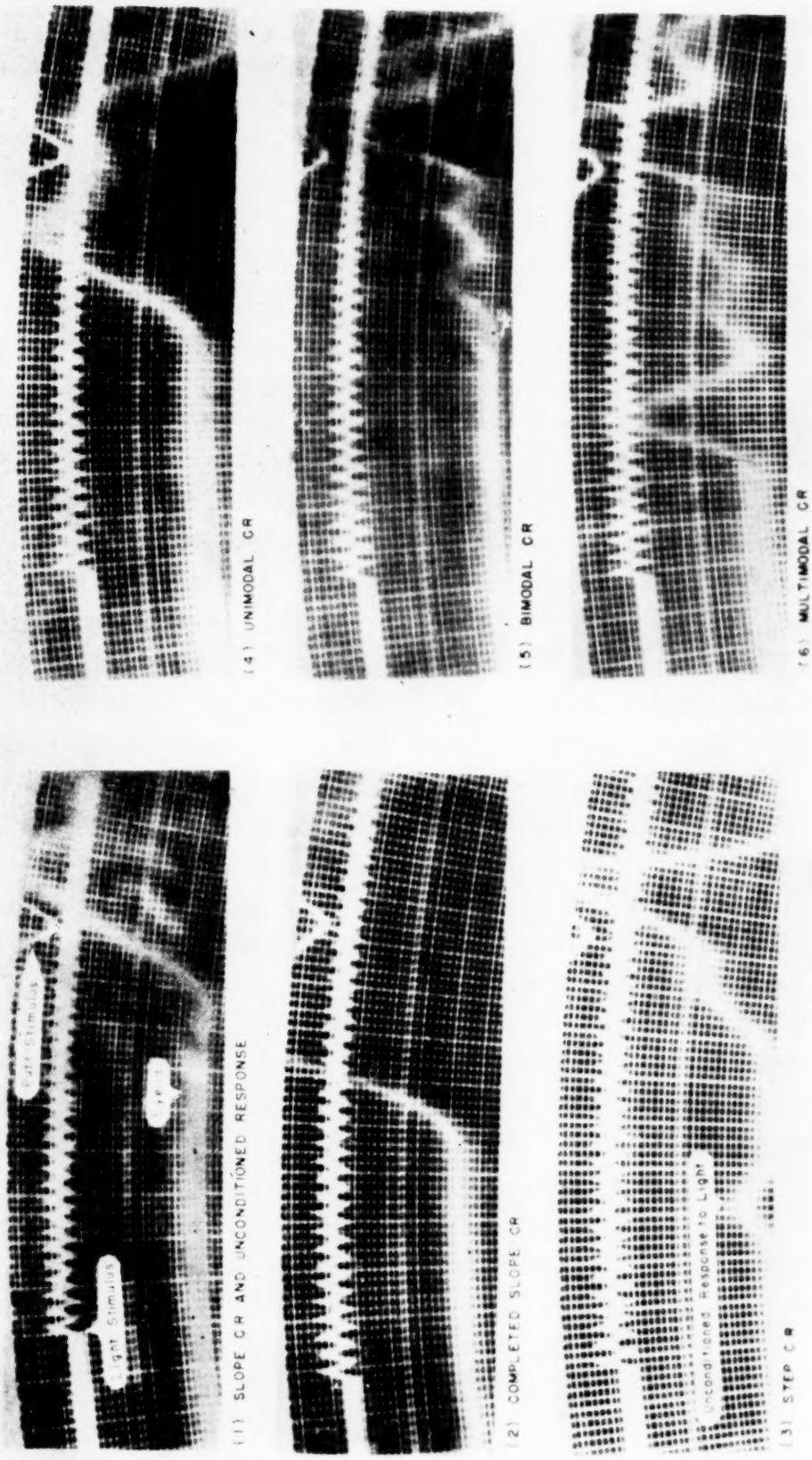

FIG. 1. Specimen records of six different patterns of the conditioned eyelid response.

of time is measured from left to right. The records of the stimuli and the patterns of the eyelid responses are labeled in the figure. A closure of the eyelid appears as a rise in the curve representing the position of the eyelid.

The initial unconditioned response of the eyelid to light consisted in several components such as pupillary contraction, slight withdrawal movements of the body, and other activities which were not recorded, as well as the response of the eyelid which was recorded in detail. The pattern of the unconditioned eyelid response to light usually consisted in a single partial closure followed by a reopening which varied somewhat in amplitude and latency. The recorded form of the response was symmetrical. The closure and opening took about the same time and proceeded at about the same rate. An example of this unconditioned response pattern is shown in Fig. 1. Although this pattern represents the typical lid response to light of all subjects reported in the present study, it is not necessarily the 'typical' unconditioned response pattern of the eyelid to light. The unconditioned responses of two other (unreported) subjects were so prolonged and complicated that their data could not be used since it would have been almost impossible to distinguish a conditioned response from the unconditioned response to light alone.

The main change in the unconditioned response to light consisted in a gradual decrease in amplitude and frequency as the experiment progressed. This result as far as amplitude is concerned was reported by Hilgard and Campbell (7).

The original unconditioned response to the puff of air varied considerably from individual to individual. In a few subjects the response was quite diffuse and consisted in winking, withdrawal of the head from the head-rest, and exclamations. However, the response to the air-puff became less diffuse with succeeding trials and was soon limited for the most part to the response of the eyelid itself. There were more variations in the patterns of the unconditioned response to puff obtained from different subjects than in the patterns of the unconditioned response to light. The most frequent patterns involved single or double closures, and the recorded

patterns resembled various types of unimodal and bimodal frequency distribution curves. Other patterns which were consistent in one or more subjects were: (*a*) single closures plus one or more fluctuations of the eyelid, appearing on the records as a single mode plus one or more quick oscillations of the eyelid about its normal open position or baseline; (*b*) single closures followed by a characteristic pause in opening which was recorded as a step on the record; and (*c*) fluctuating closures involving three or more partial closures.

As a rule, the changes in the patterns of the unconditioned eyelid response to the puff seemed to involve gradual variations from more complex to less complex forms as the puff stimulus was repeated. This trend toward simpler patterns was not without exceptions in some of our subjects, and almost all of the subjects showed occasional regressions to more complex forms.

Results on Conditioned Responses

In order to facilitate the discussion of the patterning of the conditioned eyelid responses obtained in this study, we have attempted to classify the patterns into six general types. This classification is more or less arbitrary and is based on the pattern of movement of the eyelid as recorded by the photochronographic method rather than on differences in the musculature or neural connections involved.

The justification for assuming sufficient consistency to permit classification lies in the fact that the successive records of any given subject quite often show a striking stereotype of patterning, following one of the general types of response to be described below. After showing one type of response, most of the subjects displayed another type and later returned to the original type. All of the subjects displayed two or more of the general types of response during the conditioning series.

Examination of the records seemed to indicate that all of the responses might be roughly classified under six general headings based upon the criteria of (*a*) the temporal relation of the closure of the eyelid to the onset of the unconditioned

stimulus (puff), and (*b*) the number of reversals in the direction of motion of the eyelid during closure.

Classification of the Patterns of the Conditioned Responses

The general classification of the patterns is illustrated in Fig. 1, and may be described as follows.

1. *Slope CR and Unconditioned Response (Incomplete Slope CR).*—This pattern consists of a single closure initiated before the onset of the air-puff and continuing at a fairly constant rate until closure is completed, after which opening may occur in almost any manner, although in a given subject this part of the pattern was generally stereotyped also. An example of this pattern is shown in the upper left record of Fig. 1.

In all six of the pattern types, the exact slope or rate of closure and the manner of reopening are subject to a certain amount of variation, especially between different subjects.

2. *Completed Slope CR.*—The Completed Slope CR consists of a slope closure as in the case of the Incomplete Slope pattern, except that in this case the closure is completed before and continues during the air-puff. The essential difference between the first pattern and the present one lies in the shorter latency of the Completed Slope CR, which permits completion of the closure before the onset of the puff. The Completed Slope CR may correspond to Bernstein's (1) positive fixation response, but most specific response patterns probably depend upon particular experimental conditions. None of our patterns corresponded to Bernstein's negative fixation response, and we found few tremors such as those reported by Miller and Cole (10) as being typical of their conditioned eyelid responses.

3. *Step CR.*—The Step CR consists of a partial closure of greater or less amplitude preceding the onset of the puff; and this closure is momentarily halted before completion, resulting in a step or plateau in the record when the closure is resumed under the stimulus of the puff. An example of this type of pattern appears in Fig. 1.

4. *Unimodal CR.*—This type of pattern is made up of a more or less complete initial anticipatory closure, followed by a partial or complete reopening which is then halted by a second closure in response to the onset of the puff. Due to variations from subject to subject in the nature of the unconditioned response to the puff (the second component in this dual pattern), we prefer not to refer to the second part of the pattern in naming this type. The present type of response was referred to by Hilgard (**5**) as a dual or dicrotic response. This type seems also to correspond to Bernstein's (**1**) 'typical' conditioned reaction.

Perhaps the chief difference between the Step and the Unimodal response patterns is the difference in latencies or temporal relations, for if a partial reopening were to take place in the Step Response pattern (due to delay of the puff of air), it would then be classified as a Unimodal response pattern. However, the Step patterns sometimes had prolonged steps, and the stereotyping of this pattern in different subjects seemed sufficiently common to justify its inclusion as a separate type.

5. *Bimodal CR.*—The Bimodal CR consists of two preliminary winks of greater or less amplitude preceding the puff and the following closure to the puff as shown by the fifth record in Fig. 1. The preliminary winks need not be of such low amplitude, and the unconditioned response to the puff need not be double, in order that the response be classified as a Bimodal CR.

6. *Multimodal CR.*—The last pattern type shown in Fig. 1 is the Multimodal CR, which consists of three or more partial closures or winks preceding the puff of air and the unconditioned eyelid reaction to the puff. As in the case of the Bimodal pattern, the fact that the unconditioned response is double is not important in classifying the response. In the record shown in Fig. 1, the first closure may be an exaggeration of the unconditioned response to light, and by virtue of this exaggeration, it may be regarded as a part of the conditioned response pattern.

Frequency of Occurrence of the Different Conditioned Re-

sponse Patterns.—We have counted the number of times the first conditioned eyelid response of each individual subject followed each of the different types described above. For the active group, one of the responses was a Step CR of 4 mm recorded amplitude, and six were of the Unimodal type with an average recorded amplitude of 39 mm. For the passive group, four were classified as Incomplete Slope CR with an average amplitude of 21 mm, four were of the Unimodal CR type with an average amplitude of 28 mm, and one was of the Multimodal CR type with an amplitude of 11 mm. The difference between the active and passive groups is possibly due to differences in individual response tendencies rather than to differences in group response tendencies which occurred as a result of the different attitudes of the two groups.

The first conditioned responses which are Unimodal have large amplitudes, the Multimodal and Step patterns have relatively low amplitudes, and the amplitudes of the Incomplete Slope CR are intermediate. The absence of Completed Slope patterns in this group is probably not unusual, since this very efficient pattern generally occurs later in the conditioning series.

The results on variations in frequency of the different types of patterns during the conditioning series are given in Table 1. In this table, the number of times each pattern

TABLE 1

FREQUENCY OF DIFFERENT PATTERNS OF CONDITIONED EYELID RESPONSES IN SUCCESSIVE TWENTY-FIVE TRIAL BLOCKS DURING THE CONDITIONING SERIES

Pattern	Active Group $N = 7$								Passive Group $N = 9$							
	Trials, Day 2				Trials, Day 3				Trials, Day 2				Trials, Day 3			
	6–30		31–55		6–30		31–55		6–30		31–55		6–30		31–55	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Incomplete Slope	17	25	16	14	15	10	22	14	7	14	24	30	41	26	34	20
Completed Slope	14	21	51	45	56	38	68	44	18	35	14	18	27	17	54	31
Step	13	19	11	10	11	7	23	15	1	2	4	5	12	8	18	11
Unimodal	17	25	34	30	43	29	34	22	25	49	33	42	50	32	61	35
Bimodal	2	3	1	1	3	2	1	1	0	0	4	5	10	7	2	1
Multimodal	4	6	1	1	20	14	7	5	0	0	0	0	15	10	3	2
Total CR's	67	99	114	101	148	99	155	101	51	100	79	100	155	100	172	100

occurs during each successive block of 25 trials is given together with the percentage frequency for each pattern for each successive block. In the active group, for example, the Completed Slope CR pattern occurs 14 times in the first 25 trials, and this is 21 percent of all the conditioned responses occurring in this group during the first 25 trials.

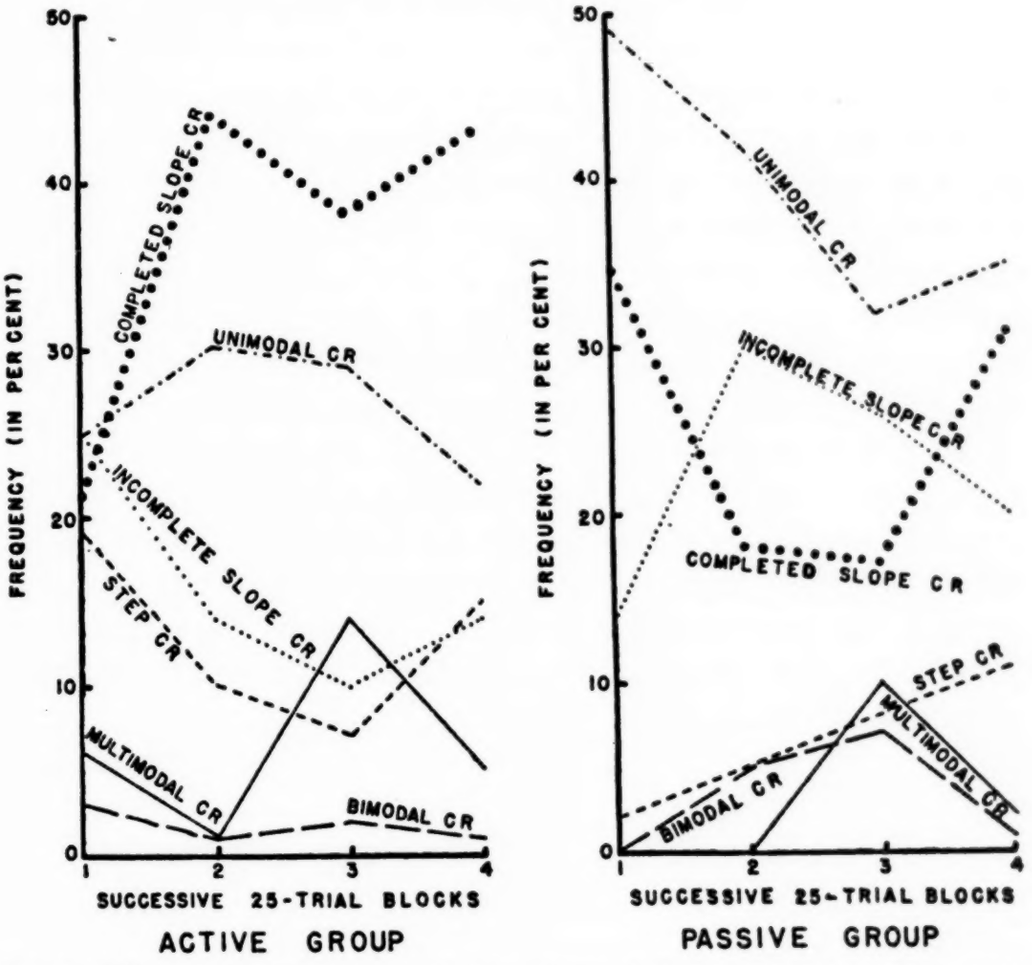

FIG. 2. The percentage frequency of the patterns of the conditioned eyelid response for successive twenty-five-trial blocks.

The two most frequent patterns in the active group were the Completed Slope CR and the Unimodal CR; and the most common patterns in the passive group were Unimodal CR, Incomplete Slope CR, and Completed Slope CR. The relatively high frequency of Incomplete Slope patterns in the passive group is in harmony with the results on the initial conditioned responses. The Completed Slope CR is most frequent in the active group, and the Unimodal CR is most

frequent in the passive group. As mentioned before, the Completed Slope CR occurs more frequently in the later stages of the conditioning process.

The percentage results of Table 1 are presented graphically in Fig. 2. There is a relatively great increase in the percentage of Multimodal CR's during the third series of 25 trials in both the active and passive groups, and investigation of some of these more consistent trends may yield valuable data on the factors which influence the patterning of learned activities.

The percentage of Completed Slope and Unimodal CR patterns is greater in the active group and the percentage of Unimodal, Completed Slope, and Incomplete Slope CR's is greater in the passive group. In both groups there is an increase in the relative frequency of Completed Slope CR's toward the end of the conditioning series and a decrease in relative frequency of Unimodal responses.

In the 5-trial series at the end of the second and third day's experimental period when light alone was presented, the only patterns observed were the Unimodal and Bimodal types. In these series, the unconditioned response to puff was lacking, and only the conditioned response part of each pattern remained. The Step CR and Incomplete Slope CR patterns could not occur.

The average number of responses of each type per subject for the second day were:

	Active Group	Passive Group
Unimodal CR	2.86	1.44
Bimodal CR	.71	0.00

For the third day, the average number of responses of each type per subject were:

	Active Group	Passive Group
Unimodal CR	4.15	2.78
Bimodal CR	.29	.56

The Unimodal response is more frequent in both groups for both days.

On the fourth day of the experiment, when light alone was presented, Unimodal, Bimodal, and Multimodal responses appeared in each group. The percentage frequency of each of these patterns in the extinction series on the fourth day was

as follows:

	Active Group	Passive Group
Unimodal CR	53	65
Bimodal CR	40	28
Multimodal CR	7	7

The only difference between the active and passive groups in the relative frequency of these patterns lies in the larger proportion of Unimodal CR's which occurs in the passive group.

Frequency of Different Patterns in the Case of Individual Subjects.—There were no consistent differences between the active and passive groups in the tendency of individual subjects to restrict their responses to certain patterns.

Two subjects of the active group who showed strong conditioning used only Completed Slope patterns in the later stages of the reinforcement series, after having first shown frequent Incomplete Slope CR, Step CR, and Unimodal CR patterns. Another subject of the active group shifted from mostly Unimodal patterns to mostly completed Slope patterns. A third subject in the same group, after presenting mainly Unimodal CR patterns, shifted to Incomplete Slope and Step patterns in the last 25 trials. Each of the three other subjects in this group used three patterns with equal frequency, except that one of these subjects showed a marked increase in Multimodal CR patterns in the third 25-trial block.

Two of the subjects in the passive group showed a preference for Unimodal CR patterns in the last two 25-trial blocks. Another subject in this group showed a pattern preference for the Completed Slope response in the last 25-trial block. The records of one subject in the passive group are particularly interesting because of shifts in preferred patterns of response. The number of Unimodal patterns shown by this subject was: for the first set of 25 trials, 12 out of 15; for the second set of 25 trials, one out of 11; for the third set of 25 trials, 18 out of 23; and for the fourth set of 25 trials, 12 out of 22. Somewhat less striking shifts from pattern to pattern occurred in the records of most subjects who showed a high frequency of conditioned responses. The remainder of the passive group

scattered their responses in each 25-trial block among from three to all six types and showed no long-time tendencies, although short series of stereotyped patterns frequently occurred in most cases.

The following detailed record of one of the subjects of the passive group for the second day of conditioning shows the number of changes in pattern which may occur during the course of reinforcement.

Trials	Stimulation	Patterns
1–5	Light alone	Unconditioned response ('UCR') to light on trials 1, 2, 3, and 4, absent on 5.
6–10	Light and puff	Trials 6, 8, and 9, Single UCR to puff. Trial 7, exaggerated UCR to light and Bimodal UCR to puff. Trial 10, Incomplete Slope CR.
11–20	Light and puff	Trials 11 and 12, Step CR with exaggerated UCR to light on trial 11. Trials 13–18, stereotyped Incomplete Slope CR. Trials 19 and 20, Completed Slope CR.
21–25	Light and puff	Trials 21 and 23, Incomplete Slope CR. Trial 22, Unimodal CR. Trials 24 and 25, stereotyped slow Completed Slope CR.
26–30	Light and puff	Trial 26, Step CR. Trials 27 and 30, Unimodal CR. Trials 28 and 29, Completed Slope CR.
31–35	Light and puff	Trials 31 and 34, Incomplete Slope CR. Trials 32 and 35, Unimodal CR. Trial 33, Completed Slope CR.
36–45	Light and puff	Trial 36, Bimodal CR. Trials 37–44, stereotyped Completed Slope CR. Trial 45, Incomplete Slope CR.
46–50	Light and puff	Trials 46, 48, 49, and 50, stereotyped Unimodal CR. Trial 47, Completed Slope CR.
51–55	Light and puff	Trial 51, Unimodal CR. Trials 52–55, Completed Slope CR.
56–60	Light alone	Trials 56–59, Unimodal CR's of progressively lower amplitude. Trial 60, no response visible.

The above summary is fairly representative, although this subject conditioned exceptionally well for a member of the passive group and was more capricious than most of the subjects in mixing the different patterns of response during the conditioning series. Appearance of exaggerated uncondi-

tioned responses to light after the first presentation of the air-puff, and with the first few conditioned responses, was observed in about half of the subjects of both the active and passive groups. These phenomena probably represent the results of the establishment by the presentations of the puff of a rather generalized response tendency which is then released by the light stimulus. This may represent an unverbalized prototype of more highly verbalized sets such as those operating in controlled association experiments.

Discussion

Investigation of the initial and later patterns of conditioned eyelid responses for each subject showed unusually high amplitudes in the initial conditioned responses of most of the subjects and subsequent shifting from pattern to pattern including reversions to earlier patterns. Many of these patterns showed a poor resemblance to the unconditioned response to the air-puff.

Hilgard (**6**), in discussing stimulus substitution in conditioned reflex theory, pointed out that differences between the conditioned and unconditioned responses in latency, amplitude, and form do not rule out the possibility of stimulus substitution, although these differences may introduce complications in the theory of stimulus substitution. However, the existence of several more or less consistent patterns of a conditioned response in the same subject, together with progressive and regressive shifts in patterning as reinforcement continues, seems to present further complications to conditioning theory and especially to the doctrine of stimulus substitution.

Since all of these patterns are initiated by the same external stimulus and end in a closure of the eyelid, all of the patterns may be regarded as a 'habit-family' (**8**), or each of the patterns may be regarded as a member of the same 'habit-family.' The question may be raised as to whether the whole 'habit-family' is conditioned as a unit or whether each response is conditioned separately. And if the whole 'habit-family' is conditioned as a unit, through what process does this conditioning take place?

Our data do not give final answers to these questions, but the results do give some indication of the direction of the answers. The very high amplitudes of some of the initial responses and the frequent shifts from pattern to pattern suggest that the 'habit-family' may be conditioned as a whole, although one or two of its members may also be conditioned separately. In some cases, the process involved in this conditioning was the general set to close the eyes, which appeared with the conditioned expectation of the puff of air. That the psychological processes of expectation of the puff and the set to respond by winking were conditioned in many of our subjects is evident from their verbal reports (**4**). Schilder (**12**) has reported the conditioning of similar expectations and similar sets to respond in his conditioned hand withdrawal experiment.

The reports of our subjects as well as those of Schilder indicate various degrees of verbal clarity in regard to the sets and expectations. The exaggerated unconditioned response of the eyelid to light, which occurred in some of our subjects one or two trials after they had received the first puff of air and which appeared with the conditioned response, is strongly suggestive of a set to respond which in most cases cannot be clearly verbalized. When the set can be verbalized, there may be several kinds of complications. The subject may realize that he has been strongly impelled to close his eyes before the puff arrives, and he may feel ashamed of himself or think that he has been tricked and thereafter try to inhibit the anticipatory closure. It may be that some of the response units of the 'habit-family' are subject to this kind of direction through verbalization, while others are not under the same control. A given response might consist of two or more interacting members of the 'habit-family.' There is also the possibility that a part of a pattern may be subject to control, while the rest of the pattern may remain unchanged in spite of attempts at voluntary inhibition or facilitation. Razran (**11**) based his theory of conditioning types in man on more or less verbalized attitudes, and Cason (**2**) has discussed the rôle of verbal activities in conditioned response

experiments. A carefully executed study of the various attitudes and sets assumed by the subject during a conditioning experiment correlated with the records of the responses should reveal much that is interesting and important in this connection.

Summary and Conclusions

Conditioned eyelid responses were obtained from 16 subjects, using light as the substitute or conditioned stimulus and a puff of air as the original or unconditioned stimulus. The pattern of the eyelid response was recorded by an adaptation of the Dodge photochronograph. Seven subjects formed an active group, and were instructed to maintain an active, expectant attitude toward the onset of the light stimulus and to make a finger tapping response when the light appeared. Nine subjects formed a passive group, and were instructed to adopt a passive attitude toward the light stimulus. The patterns and the shifts in the patterns of the conditioned responses were studied in some detail.

The principal conclusions which seem justified from the present study are as follows.

1. The unconditioned response of the eyelid to light usually appeared as a symmetrical unimodal response which decreased in amplitude and frequency of occurrence as the experiment progressed.

2. The unconditioned response of the eyelid to the puff of air was more variable from subject to subject and in the same subject at different times than was the unconditioned response to light. There seems to have been a slight trend toward simplification in this response as the experiment continued.

3. The records of the different subjects showed six qualitatively different patterns of eyelid movement, the exact form of each pattern varying from individual to individual but remaining fairly consistent in the case of a single individual.

4. The pattern type of the initial conditioned response varied from subject to subject, and some of these initial patterns were of very high amplitude.

5. An individual may produce several consistent but different patterns of conditioned eyelid response. These responses may shift from one pattern to another, and there are frequent regressive shifts to patterns which had been present in an earlier stage of the experiment.

6. Single anticipatory closures which last through the puff (Completed Slope) and closures consisting of a preliminary conditioned wink and an unconditioned wink (Unimodal) were the most frequent patterns, but neither one of these responses may justifiably be regarded as the typical conditioned response pattern. In general, as the reinforcing process continued, the proportion of Completed Slope patterns increased, and the proportion of Unimodal patterns decreased.

7. The observations on patterning suggest that a conditioned 'habit-family' was obtained through the conditioning of the underlying psychological processes of expectation and set to respond. The patterns of some of the responses of the 'habit-family' may be complicated by the influence of attitudes and verbal processes.

(Manuscript received May 26, 1939)

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SOME EFFECTS OF INTERMITTENT PHOTIC STIMULATION *

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Certain qualities of a given sensation are determined by the pattern of the afferent input from the sense-organ. Due to the variation in excitation threshold for the various sense-cells, as, for example, in vision, and due to their asynchrony of discharge and differences in discharge rate, the pattern ordinarily is very complex. Temporal and quantitative differences in the stimulus effect appropriate changes in this pattern. That is to say, qualitative and quantitative changes in sensation occur as the frequency of intermittent stimulation is made higher. For instance, psychological entities, such as flashes with dark intervals intervening, are replaced by others, and the ultimate impression, as the stimulus intermittency is made high enough, is that of uniform continuity in whatever kind of sensation is being aroused. This point has been extensively studied in vision, and is measured by the stimulus repetition frequency (critical flicker frequency, c.f.f.). Considerable has been learned about the nature of vision by such investigations.

Increase of stimulus *intensity* has the effect of raising the discharge *frequencies* of the individual sense-cells, and almost regardless of the sensory entity studied, intensity varies the necessary repetitive rate of the stimulus producing it. This is notably true of c.f.f. and has been also definitely shown for various characteristics of the electroretinogram which reveals something of the neurological nature of the visual sensory message. It is to be noted that the repetitive frequencies studied in such investigations are always below the expected

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c.f.f., or fusion point. It might be expected from this, as well as from many incidental observations and scattered studies in visual sensation under similar conditions, that additional information could be gained by studying visual sensation under repetitive frequencies below c.f.f. The following are several examples of such studies.

It has been reported that flicker shifts to glitter as stimulus frequency is slowed down to 18 per second, provided that under the conditions, c.f.f. is above this rate. As c.f.f. ascends with rising intensity, this flicker-glitter boundary is said to remain at the level of 18 per second, and thereby is independent of flash intensity (**4**). Such a boundary was not found in the present study.

Brücke pointed out many years ago that there is a rotation frequency at which the bright sectors on a revolving disc appear brighter than when stationary. This was within the stage exhibiting Charperntier's bands (the rotating dark and light sectors appearing to stand still), and accordingly, Helmholz attributed them to the process responsible for brightness contrast.

This phenomenon of enhancement has been recently studied with serial flashes of light instead of rotating discs, and it has been shown not to exist at merely a single frequency or over a very narrow band, but over a wide range (**3**). Very soon after flash frequency falls below c.f.f., the subjective brightness value of the field illuminated by the intermittent stimuli begins to rise until it reaches a level equivalent to that obtained with continuous stimulation, which it then exceeds, reaching a maximum at about 8 to 10 flashes per second. The maximum brightness with reference to the brightness produced by continuous stimulation is the reciprocal of the Talbot level, and the whole trend away from the Talbot level is to be thought of as the Brücke effect.

Between 17 and 18 stimuli per second was the frequency that Brücke reported for his phenomenon of brightness enhancement, and it is plausible that he was in some way identifying the flicker-glitter boundary and enhancement itself, and in so doing failed to discover the actual enhance-

ment maximum in the neighborhood of 10 per second. There is, however, an essential difference between the set-up of Brücke, in which bright, apparently stationary bands were viewed alongside of darker ones, and Bartley's investigation of enhancement, for in the latter case the field around the test-object was unilluminated. This difference, then, might account in part for the location given by Brücke to the enhancement.

My purpose has been to outline the major qualitative transitions in visual sensation as flash frequency is reduced from c.f.f. to the point at which each flash is seen as an individual and to ascertain their possible relation to physiology. It was not possible to point out the neurological correlates in all cases.

Method

Three arrangements were used, the first providing a test-object of small visual angle and whose upper intensity limit was higher than that easily attainable for large test-objects. The second was the same arrangement as used in a previous study on gamma movement (2), and provided a test-object whose maximum visual angle is about 50 degrees. Diaphragms were inserted to reduce the test-surface to subtend smaller visual angles. The optical system provided that the illumination of all portions of the test-surface was simultaneous in its onset and decay, thus eliminating any possible qualitative artifacts due to 'sweep' across the field. The intensity ranges used are indicated in the diagrams giving the results. The third set-up was a Macbeth Illuminometer Head in which its test-field was used for the test-object and the standard field or annulus was used as the surround.

Results

Disregarding absolute values, the series of changes which typically occur as flash frequency is reduced from the sensory fusion point when the test-object is not surrounded by an illuminated field is as follows:

First, slight transient fluctuations (flicker) appear in the test-field, which are so slight as to escape all but the most careful fixed scrutiny. If the test-field subtends a large visual angle (let's say, 10 to 50 degrees or more), this minimal flicker first appears only in minor parts of the field. As either intensity is raised or flash frequency is lowered, flicker becomes more pronounced and its apparent rate possibly slightly lower. It begins to cover the whole test-field, al-

though, if the field is large, not uniformly. While it is yet weak enough to appear secondary to the general brightness level of the test-field, the fluctuations retain their original qualitative features, but as their frequency is further reduced, they become more vigorous and the field takes on a mottled appearance. The onset of the latter is almost too gradual for one to fix a transitional point. With further reduction, if the test-area is small (up to possibly 10 degrees v.a.), definite flicker can be seen outside of the visual field of the test-object. At first it is only close around it, but as the flash frequency is reduced still more, a point is reached at which the whole field begins to flicker. This transition and the one just preceding it are relatively abrupt. With lower and lower frequencies the fluctuations become more and more vigorous until they produce a marked feeling of ocular tension or effort, as if the pupillary muscles were trying to relax and contract in unison with the appearance of the dark and light intervals. The maximum of this tension is reached (with equal light and dark intervals in the flicker cycle) just prior to the frequency at which the dark phase of the cycle emerges in sensation as a shadowy entity. As the flashes are repeated still more slowly, the dark phase of the cycle becomes more and more pronounced until the flashes are seen as definite entities with distinct dark intervals between. Especially throughout this part of the range the time and manner of appearance of some of the sensory features are determined by the light-dark ratio of the stimulus cycle.

The nine stages, including the Brücke maximum, that have been enumerated are illustrated in Fig. 1. With high flash frequencies there is (1) a steady field or fusion. With lower and lower frequencies there are the following stages: (2) slight flicker in relatively steady fields; (3) a mottling of the test-field, and coarser flicker; (4) flicker in the field surrounding the test-object when it subtends a small or medium visual angle, and the beginning of an appreciable amount of gamma movement; (5) flicker is seen over the whole visual field outside the test-object, and vigorous flicker within the test-field when it subtends a large visual angle, gamma movement

becoming vigorous; (6) the Brücke maximum; (7) the development of definite ocular tension; (8) the emergence of the dark phase of the cycle; (9) the emergence of the flashes and dark intervals as entities.

These stages involve a series of boundaries—(*a*) critical flicker frequency between 1 and 2, (*b*) a very poor boundary between 2 and 3, and (*c*) a distinct one between 3 and 4. If

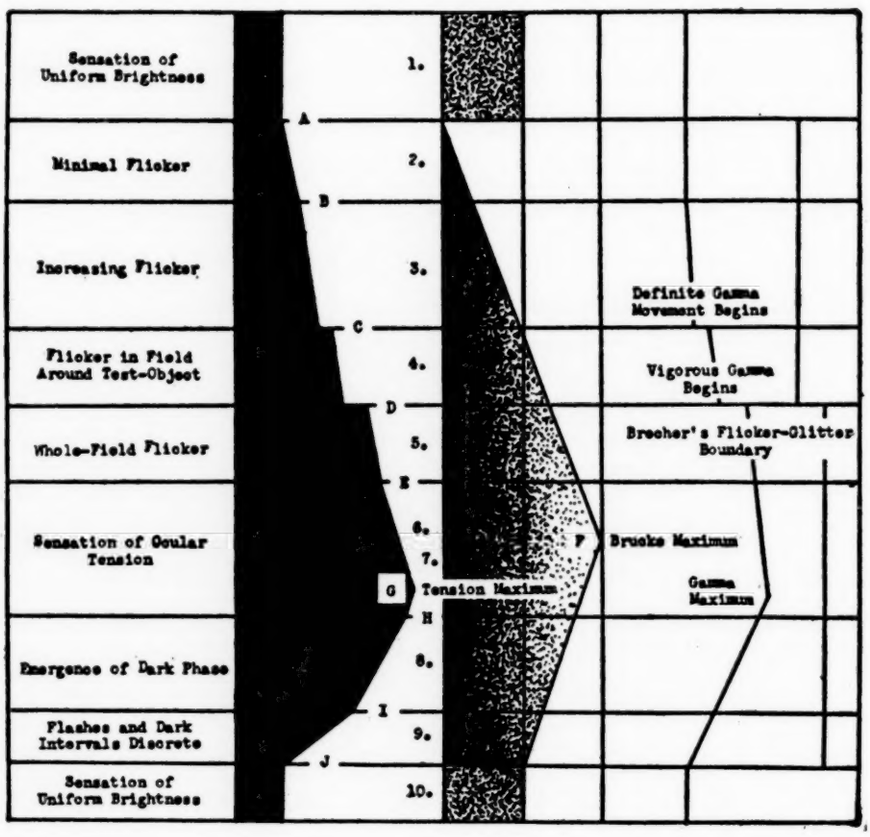

FIG. 1. A diagram showing the salient subjective stages as flash frequency is reduced from the fusion point to where flashes and intervening dark intervals are seen as discrete entities. The degree of abruptness of the transitions is suggested by the right hand border of the dark area. The ocular tension maximum, Brücke maximum, and the point at which gamma movement is most vigorous are also indicated.

this is the boundary at which glitter begins to appear, it is much higher than the one measured by Brecher. (*d*) A marked boundary between 4 and 5. Here flicker appears over the entire visual field, and the result is the possible glitter of Brecher, indicated both on account of its qualitative appearance and on account of the frequency level at which it is found comparing most nearly with his flicker-glitter boundary. (*e*)

The beginning of ocular tension. (*f*) The Brücke maximum, which can be considered as a boundary or a stage. (*g*) A point of maximum muscular tension in stage 7, and (*h*) the point of emergence of a dark phase (between regions 7 and 8), and (*i*) the beginning point of discreteness of the flashes and dark intervals.

Though the phenomena just enumerated are quite definite, the correlation between them and the neurological events they depend upon is not as yet apparent in all cases and only some of them will be singled out for discussion.

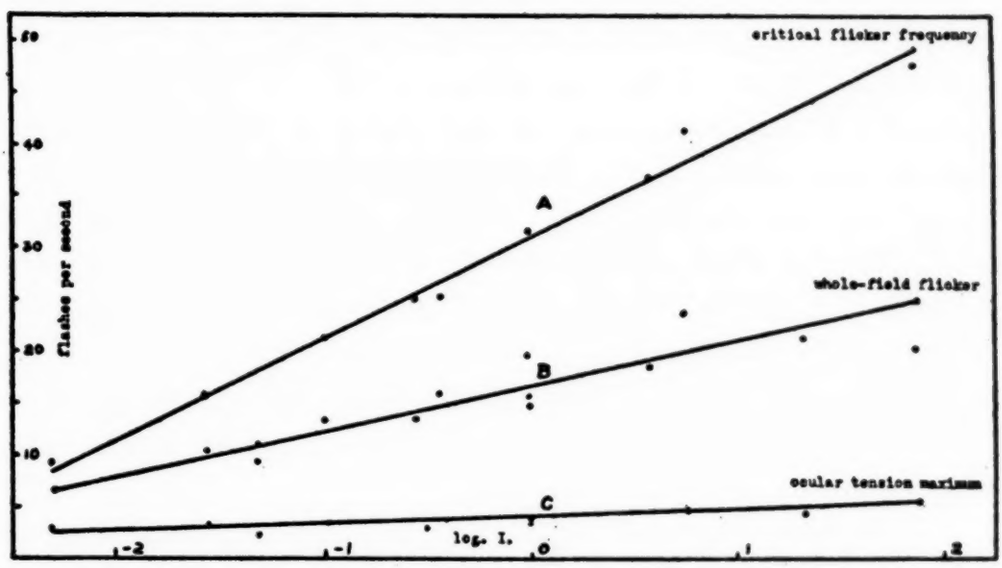

FIG. 2. Curves showing the relation of flash frequency to intensity (log *I*) in determining c.f.f., the place of whole-field flicker, and of maximum ocular tension. The late dark-ratio was 0.5. Intensity is in c./ft². The functions behave quite similarly.

Figure 2 shows the behavior of three of the transitions measured for a test-object subtending a visual angle of 3 degrees, when intensity is varied. Curve *A* is for c.f.f., and is linear throughout the range used. Curve *B* is for the point at which the whole field just began to flicker when flash frequency was reduced. It is stretching the truth a bit to call this a flicker-glitter boundary, but in our search for this boundary it was the transition point which most nearly compared to the flicker-glitter boundary reported by Brecher. At this point the field has a very showy type of fluctuation, but it is not anywhere nearly like the glitter that appears when the

field surrounding the test-object is illuminated. The transitions with such a set-up will be described in a later section. We shall simply call this boundary *D*, as indicated in Fig. 1.

Bartley (1) showed that flicker in the visual field as a whole, outside of the test-object, is determined by the intraocular stray light, which is reflected onto the retina from the retinal image, consequently both its area and intensity determine the intensity of stray illumination of the retina as a whole, and thus the c.f.f. of the retinal field outside the image. It happens in the present case that the retinal image is just large enough to provide enough reflected light on the retina-as-a-whole to place the boundary for whole-field flicker at one-half the level of the test-object c.f.f.

Curve *C* is for point *G*, or the point of maximum ocular tension. It, also, with light-dark ratio of 0.5, is linear throughout the range tested. With other ratios, that is to say, when the flash occupies only a small part of the intermittency cycle, or else occupies most of it, a maximum is reached when the flash intensity is raised, beyond which the flash frequency for obtaining it falls (Fig. 4). It would seem that the same conditions cause this as cause the c.f.f. curve to reach a maximum and recede.

The experience of ocular tension would lead one to suppose that the pupillary reflex mechanism were trying to follow the alternation of light and dark. This supposition has not as yet been systematically tested, though some incidental observations relative to the ability of the pupil to contract and dilate with slow alternations of light and darkness indicate that it can do this. On the other hand, the findings of Crawford (5) in which he noted pupillary dilation over long intervals after the cessation of illumination show the change to be far slower than necessary in the present case. It may be that the pupil is not actually able to contract and dilate at the rate called for in this case, but instead a fluctuation in tension is instituted, too little to measure instrumentally, but sufficient to experience.

It seems the very fact that discomfort is produced must be laid to some muscular effect, rather than to the direct effect

of light itself on the photoreceptor mechanism. The behavior of the pupillary reflex and accommodation under these conditions needs to be tested, the former feat perhaps requiring, for best results, the use of infra-red photography.

On the other hand, were it to be shown that ocular muscles have no role in this experience of discomfort or tension, it would be a demonstration of an experience akin to pain being elicited by sensory stimulation of the strictly visual mechanism.

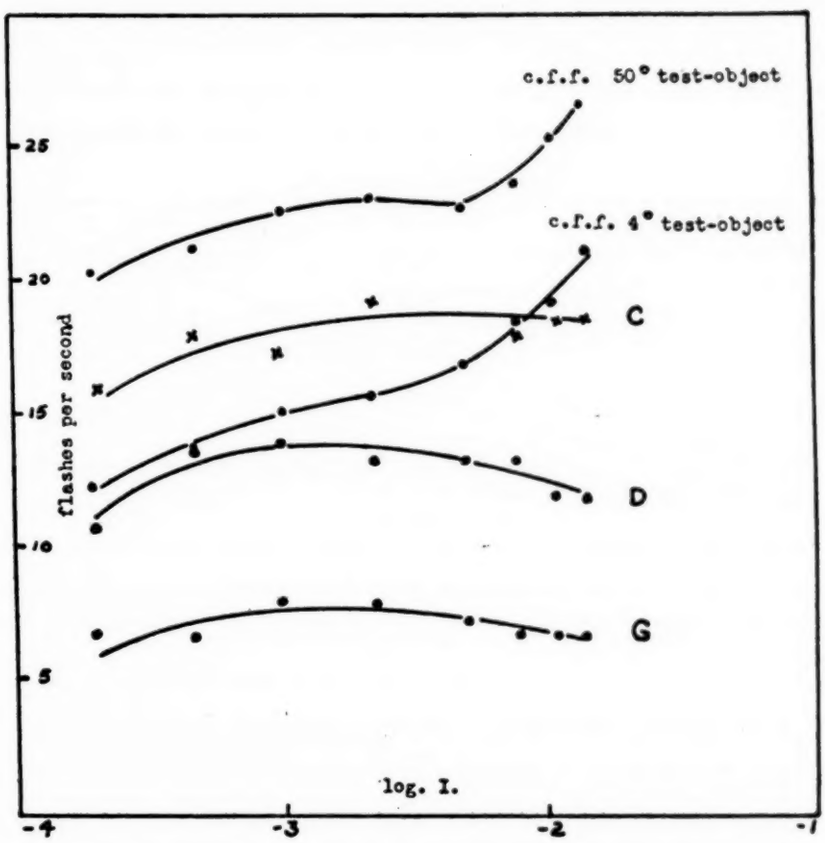

FIG. 3. Curves showing the relation of intensity to flash frequency for each of two sizes of test-object. *C* is the frequency boundary for flicker around the test-object, *D* for flicker in the whole-field, and *G* for the feeling of maximal ocular tension. The intensity, which is given in c./ft.^{2}, is so low that only in the upper range are the cones activated.

Figure 3 shows c.f.f. and boundaries *C*, *D*, and *F* for a test-object subtending a visual angle of about 50 degrees, and also c.f.f. for a test-object subtending a visual angle of 4 degrees. At the low levels of illumination used, the c.f.f. curves for the two areas rise only very slowly throughout all but their upper

ends, due to the fact that only rods were being stimulated. That the illumination finally rose to a level sufficient to stimulate cones was evidenced by the later abrupt rise in the curves. The curves for the boundaries *C* and *D*, the first and second points at which flicker appeared to become suddenly increased, did not likewise rise at their upper ends. The levels of these curves relative to c.f.f. roughly compare to the places at which flicker first appears around the test-object and the point at which whole-field flicker begins, respectively, with smaller test-objects. This and the fact that the curves did not rise at their upper ends when the illumination became strong enough to stimulate cones, suggest that these levels possibly have a common basis with those when small test-

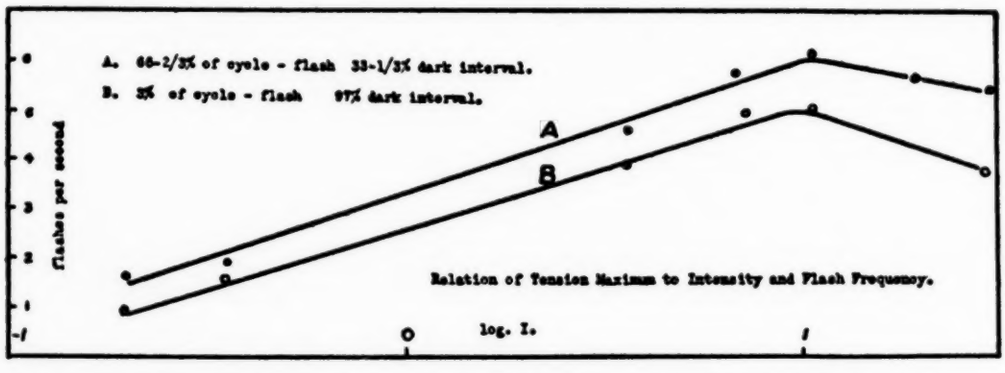
A. 66-2/3% of cycle - flash 33-1/3% dark interval.
B. 2% of cycle - flash 97% dark interval.
flashes per second
A
B
Relation of Tension Maximum to Intensity and Flash Frequency.
log. I.

FIG. 4. Curves showing the relation of the impression of maximum ocular tension to flash frequency and intensity. The L.D.R. in each case is indicated. Intensity is given in c./ft².

objects are used; namely, the action of intra-ocular extra-imaginal stray-light. That the curve for boundary *D* even descends rather than ascends may be due in part to the fact that as intensity is increased, the activity persisting after each flash is sufficient to reduce the differential between the activities in the bright and the dark phases, thereby reducing the level of the boundary between whole-field flicker and its absence. The same seems to account for the reversal in the 'ocular tension' curve, or the curve for boundary *G*, when the light-dark ratio was shifted in either direction from 0.5, as is illustrated in Fig. 4. The critical conditions for the appearance of the tension maximum are those which provide for the two things, a maximum constant tension component along

with a maximum fluctuating one. In visual terms, the conditions are those for an alternation between the greatest extremes of flash brightness and darkness, without having excessive duration or prominence of the dark interval cut down the general impressiveness of the alternation. In neurological terms it must mean that the conditions are those which arouse maximum activity, coupled with a dark interval which will allow the residual activity to fall to a minimum before the appearance of another flash, the arbitrary light-dark ratio being controlled by the fixed nature of the disc used.

If the flash is too bright or too long, its persisting residue of activity will occupy the dark interval at too high a level, thereby reducing the differential of activity between the responses in the two phases. If the dark interval is too long, it allows too much of a gap in the activity.

Test-Object with Illuminated Surround

The sensory phenomena elicited when the test-object is surrounded by an illuminated field exhibit somewhat different features. These are described in the following sections.

Figure 5 indicates some of the outstanding stages, beginning just below c.f.f. with marginal flicker, followed by coarse flicker, which, relative to c.f.f., begins at about the same relative level as flicker around the test-object does in the first experiment. The upper part of this band and the band of marginal flicker cover the same range as when the illuminated annulus is not used. Part way down through this band the border of the test-object begins to flutter, and continues to do so until flash frequency becomes quite low. The two phases can soon be seen to overlay each other. In the middle of the band is another one, in which true glitter is very predominant. The upper boundary of the glitter band is the lower end of the coarse flicker band. When flash frequency is reduced to the place where the phases scarcely overlap each other, the black of the dark phase takes on its full strength. The two phases are now beginning to take on complete identity. This is soon accomplished. The number of aspects

to be observed in this experiment is greater than when the surround of the test-object is dark, and the boundaries between the stages do not constitute a single series, but rather a series for each aspect. On this account it adds nothing to the clarity of the situation to number them as in the first experiment.

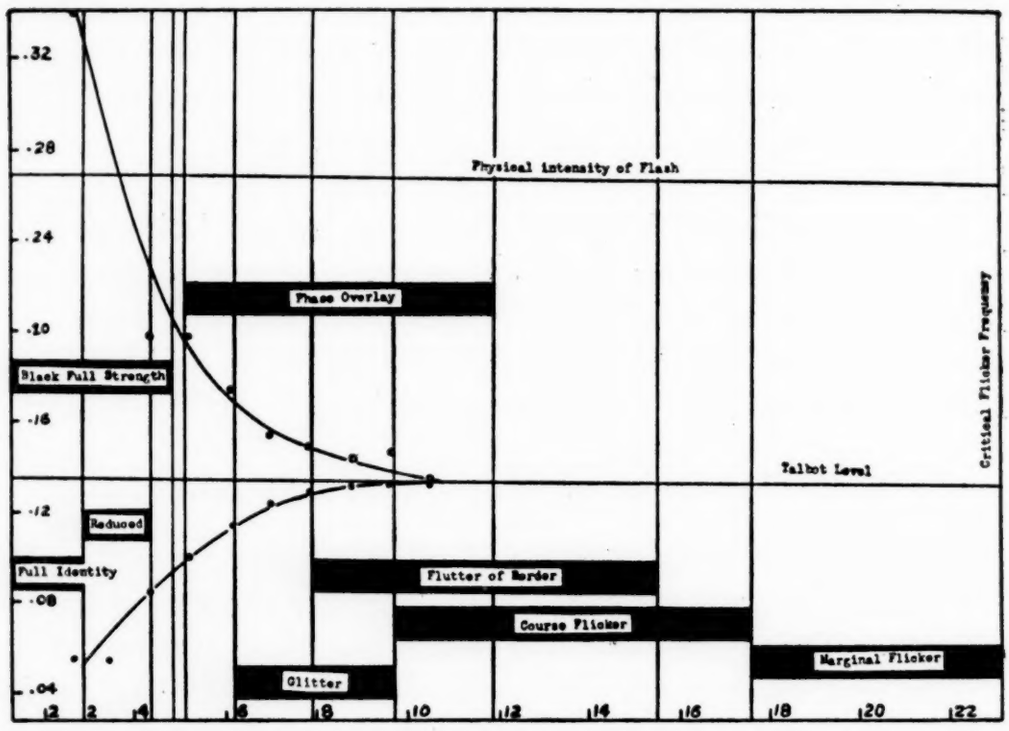

FIG. 5. Diagram showing the location and extent in the flash frequency scale of the bands within which a specific sensory aspect appears. The two curves show the intensity level of the illuminated surround, necessary for the two phases of the cycle to just predominate. The upper curve is for the dark phase to predominate, the lower for the light phase, at the frequencies indicated. This diagram is to be compared with the one in Fig. 1, outlining the sensory stages in the flash frequency scale.

It is known that the brightness of the area surrounding a test-object helps to determine its critical flicker frequency (7, 8, 9). Below critical flicker frequency the brightness of this surround also determines which phase of the flicker cycle is predominant in sensation. Flash frequency is likewise a factor in determining the level of the annular surround for one or the other phase to predominate. To show this, the head of a Macbeth illuminometer was used, the test field of which was intermittently illuminated at various frequencies ranging from 2.64 flashes per second to 10.56 in ten equal steps.

For each step the standard field or the annulus was adjusted in intensity until first the black disc alternately appeared and disappeared; the bright phase being simply a bright blurry shadow without the contour of the test-area. Next, the intensity of the annulus was lowered until a bright disc was seen to alternate with a dark shadow, whose contour also was indistinct.

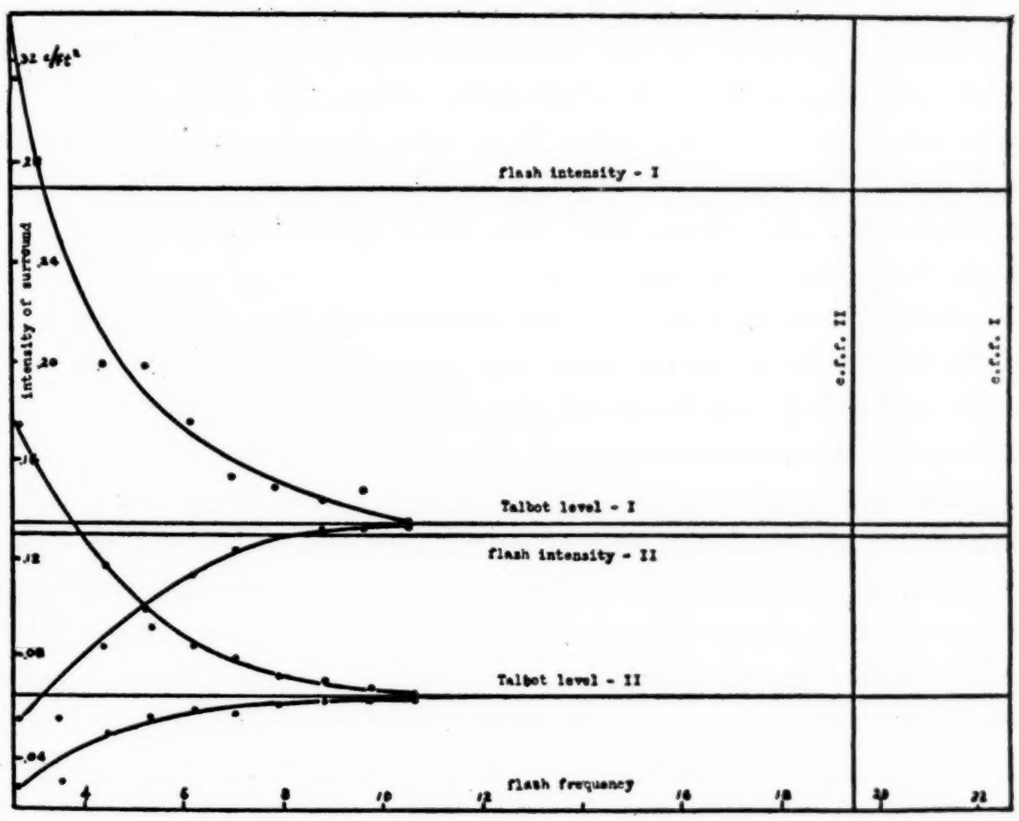

FIG. 6. Two curves showing the relation of the intensity level of the surround to flash frequency for producing a sensory predominance of either of the two equal-length phases of the flicker cycle. The upper curve is for the predominance of the dark phase, the lower for the bright phase. Intensity is given in c./ft.^{2}, and flash frequency in flashes per second. The physical intensities for the two sets of conditions, as well as the Talbot levels and c.f.f.'s, are indicated.

The curves in Figs. 5 and 6 show the annulus levels necessary to do this for the various flash rates. It will be seen that in order to subdue the bright phase sufficiently to cause the black phase to predominate, the intensity of the surround (when flash frequency was very low) had to exceed not only the Talbot brightness of the test-field but the actual brightness of the flashes themselves. As flash frequency was increased,

this level became lower and lower until it reached the Talbot brightness of the test-field. In other words, the flashes became less and less bright as c.f.f. was approached, although the Talbot brightness of the test-field was reached somewhat below c.f.f.

In order that the bright phase predominate at least sufficiently to just appear as a disc brighter than the surround and be seen to intermittently disappear or be replaced by a shadow, the level of the surround was reduced to less than one-half of the Talbot brightness when the flash frequency was 2.64 per second. This level was raised gradually to the Talbot brightness at about 10 flashes per second. This means that the dark intervals were becoming less dark as flash frequency was increased.

While flash frequency was low enough for the flashes and dark intervals to have their own complete identities (in this case 2.65 p.s.), the level of the surround had to be as much *above the physical intensity* of the flashes for the black phase to just predominate as the level had to be *below the Talbot level* for the bright phase to predominate. When the flash frequency reached about one-half c.f.f., the two curves came together and the subjective brightness fluctuation caused by the alternation of the flash and dark intervals became very slight in comparison to the constant component of the field. The fact that the sensory state begins to settle down to minor fluctuations at one-half c.f.f. is reminiscent of the cortical response whose varying latency with change in flash frequency indicated that alternation of responding elements (further asynchrony) began definitely to develop at this stage (Bartley).

Glitter

At a flash frequency of about 6 per second the glittery alternation of the two phases set in and continued till flash frequency reached about 12 per second. In this stage the characteristics of the test-object are quite like those observed when a bright and dark field are viewed stereoscopically, one seen by the one eye, the other by the other eye. The glitter maximum is reached at about 8 per second for this

level of illumination; from then on it gradually diminishes to zero. Though not a great deal of change in the location or length of the glitter band could be expected with different levels of flash intensity, the rates included would not be absolutely fixed, and independent of intensity.

It will be noted from Fig. 5 that the glitter range does not occupy all of the phase overlay range, but only the middle portions. It is this portion, however, in which both the dark and bright phases are to be seen simultaneously as though one overlaid the other, the aspect which most closely simulates the stereoscopic sensation. In stereoscopy the sensory messages of the two eyes are projected on the same cortical areas and effect either a blend, combination, or alternating dominance of one or the other, although the sensory messages themselves are streaming in simultaneously and continuously from both eyes to the point at which this takes place.

Since in the present case monocular vision is used, and the sensory input alternates from instant to instant, producing the same ultimate effect as in stereoscopy, it is quite likely that in the latter there is alternation involved in the use of certain circuits. Furthermore, it would seem probable that the order of its rate would be indicated by the flash frequencies in the glitter range in the present experiments.

Glitter is a sensation which did not arise when the test-object was free of an illuminated surround. Glitter thus represents one essential difference in the sensory outcome with and without constant illumination in the surrounding field, and leads us to inquire what the essential difference on the physiological level is in the two cases.

The effect of the surround psychologically is to form a level for comparison, so that the bright phase in the laternating test-field is brighter than it, and the dark phase darker. When alternation is adjusted to the proper rate, the two phases can be seen as virtually simultaneous. This, with the conditions just mentioned for making the maximum contrast with the surround, produces glitter as one of the predominating outcomes. Without the illuminated surround, the light and dark phases do not stand out so well in contrast

but tend rather to contribute toward the seeing of an average level of brightness.

Naturally, this has a neurological basis, and the elucidation of it would be the explanation for brightness contrast, both simultaneous and successive. Since we know that such contrast is dependent upon the relative sharpness or blurriness of the borders involved, we can say that herein we have another case in which border-forming processes likely have a part.

Gamma Movement

At about 8 per second the border of the test-object becomes unsteady and loses its sharpness. This blurriness and fluttering of the border gradually diminishes until flash frequency reaches about 15.5 per second. This flutter of the border is one form of gamma movement, though instead of the expansion-contraction aspect always predominating, a sideways movement is most noticeable, as if the convergence of the eyes were imperfect. Whatever the cause, the flutter disappears with sufficiently high flash frequencies. When the level of the annulus is lowered below, or raised above the Talbot brightness, the subjectively predominant phase becomes steady and the movement resides in the minor phase, which is little else than a shadowy sweep across the field. The overlap boundaries are also shown in Fig. 5.

Brightness of Flash vs. Steady Illumination

The intensity differential between the surround and the phase involved is probably not great in the curves in Figs. 5 and 6. If this be so, they indicate the approximate brightness levels of the two phases as flash frequency is increased from isolated flashes to approximate fusion. The level of the bright phase relative to flash frequency is then much different than in the case without an illuminated surround, in which case the Brücke effect reaches its maximum at 8–10 flashes per second. In the present case, *isolated* flashes are the brightest; in the other, *flashes at 8–10 per second*, and they are even more intense relative to the physical energy producing them than the isolated flashes in the present case, both of which

are brighter than continued illumination at the same physical level. This turns out to be an added reason for believing the Brücke effect to be of neural rather than photoreceptor origin.

Contours

Since the level of the surround determines which of the two phases becomes contoured, it may be said that we were measuring the intensity difference necessary between the surround and the test-area for contour formation at the various flash durations. When the surround was at the Talbot brightness, both the dark and bright phases were contoured. That is to say, their levels were equidistant and quite different from the level of the surround. When the surround was raised, the bright phase became weaker, less noticeable, and more poorly contoured, until it became only a spatially indefinite bright shadow, appearing to occupy less of the cycle than the dark phase which now became a definite dark disc intermittently erased. This is just a specific case of showing that contours in sensation may vary in sharpness independently of the retinal image, and that for any degree of goodness of contour, a certain amount of time and a certain intensity differential are necessary.

The test-object used by Werner (**10**) shows essentially the same type of effect of one part of the field upon another part inclosed by it. Werner presented a solid black disc on a white background, following it in rapid succession with a black ring whose inner border was the outer border of the disc. Provided that there was a sufficiently rapid succession, the *black disc disappeared.* In some cases the area within the disc became even brighter than that outside it. The rate of succession necessary for this phenomenon lay within the range for apparent movement of two figures of this size whose centers instead of being identical were some distance apart. Two further facts are to be noted. If black and white are reversed in the figures, so that the latter are white and the background black, the phenomenon of the disc disappearance is the same. If the succession is reversed, so that the disc is presented first, and then the ring, the disc will never vanish at any rate of

succession. Werner took his experiments as a demonstration of the way borders or contours are built up or are prevented from being built up.

The effect of one retinal area upon another, even though not inclosed by it, the two being stimulated in rapid succession, was shown by Fry's (6) arrangement pictured in Fig. 7. He

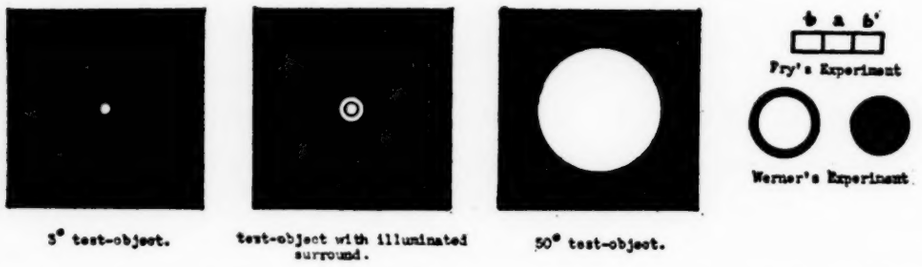

FIG. 7. Illustrations of the three different visual fields used. Their specifications are indicated underneath them. In Fry's experiment *a* was given first, and then patches *b*, *b'*. The depression of the first stimulus was the same if *bb'* preceded *a*. In Werner's experiment the disc was given first and then the ring. A longer interval elapsed and then the pair was presented again. This repetition was repeated indefinitely. The disc tended to disappear, and in a few cases the area tended to be lighter than the general surroundings.

found that with a certain rate of succession the area stimulated later reduces the subjective brightness of the first. When the two are spatially adjacent, the effect is at its maximum, diminishing to zero when their separation is slightly greater than the width of one of the areas, although he does not state the visual angle involved.

The fact that the c.f.f. of a test-object is affected by an illuminated surround was explained by Fry and Bartley (7) by assuming that the latter differentially depressed the two phases of the flicker cycle. Flicker is observed when there is a physiological differential in the two phases of the cycle, the bright and the dark. The surround first depresses the weak phase, thereby raising the c.f.f. The surround when made more intense depresses the strong phase also, reducing the difference between it and the weak, thereby lowering the c.f.f.

The foregoing facts bear upon various questions in connection with object perception and brightness discrimination. It may be said that the *temporal* and *intensity thresholds* for

seeing contour are very much higher than for seeing a mere momentary something more or less vague or shadowy. Werner in explaining the disappearance of his disc states that a figure is conceived from the point of the strongest psychophysical difference which is its contour, and on account of this if the contour cannot be formed the optical stimulus becomes psychophysically ineffective. This may be only relatively true. He continues by saying that the disappearance of the disc was due to the fact that the contour formation of the disc was identified with the inception of the construction of the ring. Fry's experiment showed that a second area will depress the brightness of an area presented just prior, even when contours are not eliminated or utilized in the way Werner assumes. The present experiments emphasize the fact that *areas* are dependent upon temporal factors for their subjective brightness, which varies widely even when the contour aspect is held constant, so that though in some cases contour formation may become critical for minute-brightness distinctions between one area and another, it is not always the critical process. Areas have an internal basis for existence, as well as a dependence on external relationships.

Summary

The major qualitative sensory changes throughout the range from isolated flashes to c.f.f. were enumerated for test-objects both with and without illuminated surrounds.

The Brücke phenomenon, which appears when comparing repeated flashes with a steady field nearby, does not appear when the fluctuating field has an illuminated surround.

In the latter case, the maximum brightness is obtained with isolated flashes, which for their energy are not so bright as the level represented by the Brücke maximum.

Glitter was observed within a narrow range part way between the terminals of isolated flashes and c.f.f. when using an illuminated surround, but not with a dark field. The location of this band was far below the 18-per-second station of Brecher's flicker-glitter boundary, which in the present experiments could not be discovered.

All of the transitions noted tended to vary with intensity, even if within small limits.

(Manuscript received May 13, 1939)

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COMPARATIVE EFFECT OF COBRA VENOM AND OPIATES ON VISION *

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INTRODUCTION

During the last few years cobra venom has been employed by French and other clinicians in Europe, Chopra in India and by Macht and his collaborators in the United States as an analgesic or drug for the relief of pain. More recently, through the work of the senior author (**1**) and that of Gayle and Williams (**2**), its usefulness as a sedative as well as analgesic in certain nervous affections, such as Parkinson's disease, has also been discovered. Injections of a sterile solution of cobra venom in minute doses were found to be effective in relieving the pain of over 60 percent of series of patients suffering from advanced malignant disease and also from certain chronic neuralgias such as tic douleureux, arthralgias, and the crises of locomotor ataxia. Comprehensive references to literature on the subject may be found in the papers of Macht (**3**, **4**, **5**), the French scientists, Lavedan (**6**) and Gautrelet (**7**), the Brazilian Klobusitzky (**8**) and the Indian investigators, Chopra and Chowhan (**9**).

Extensive laboratory investigation and clinical observations of the senior author and his co-workers have thrown some light on the *modus operandi* of this new and interesting remedy. Thus it was shown that the analgesia produced by cobra venom is a central one (**10**, **11**), *i.e.*, that the drug does not act as a local anesthetic for nerve endings or nerve fibers when administered in very dilute solutions but exerts a specific pain-relieving action through depression of pain centers in the brain. In this respect the analgesic properties of cobra venom are broadly similar to those of morphine and other

* Read before the joint meeting of the American Physical Society and the Optical Society of America at Columbia University, New York City, Friday, February 24, 1939.

opiates such as heroin, codeine, dilaudid and pantopon (**12**). There are important differences, however, in the respective pharmacodynamics of cobra venom and the opiates and other analgesics, as Macht and his collaborators have demonstrated. Thus, for instance, it has been shown that the analgesia effected by cobra venom comes on but slowly and is of long duration while that of morphine is rapidly induced but quickly dissipated. This is probably due to rapid destruction of the narcotic by the brain tissue (**13**). It is common knowledge that morphine leads to habituation necessitating progressively larger doses and results in addiction to the drug, but neither addiction nor withdrawal symptoms have been noted after administration of cobra venom during the past few years. Cobra venom is further distinguished from morphine by the fact that it does not cause the nausea and vomiting produced by the latter in a vast majority of patients. Seldom, if ever, has cobra venom such an effect, the nausea occasionally reported in connection with its use being generally attributed to the patient's neurosis and fear of snake venom. During the past year the writers have made comparative studies of the physiological effects of cobra venom and other analgesics, particularly morphine and its derivatives, not only on the sensation of pain but on other sensations—specifically vision and audition—and other psychological functions. In the present paper the writers report the results of their experiments on vision.

Methods of Study

Quantitative measurements were made of (1) the acuity of vision and (2) the field of vision of thirty-five normal individuals, who for the most part were college students and members of the laboratory staff. Acuity of vision was tested by means of standard reading charts uniformly illuminated. Subjects were required to read certain lines of letters or numbers at a distance of 6 meters or 20 feet. As most of them were in good health and either had normal vision or wore spectacles to correct refraction defects, all the tests were made with both eyes. Readings were made *before* and at one or more intervals *after* injection of the drug.

The field of vision of the same individuals was measured by means of a standard self-registering perimeter. Subjects sat with their backs to the light and care was taken to eliminate glare. In this series of tests but one eye, generally the right, was examined. The field of vision of each of the thirty-five individuals for white, blue, red and green, respectively, was carefully recorded. Throughout their investigation the writers measured both acuity and field of vision of each subject before and after ad-

ministration of the drugs on the same day, thus eliminating interference of such factors as changes in the weather, individual moods, etc.

Effect on the Acuity of Vision

The following dosages of the narcotics were employed: morphine, 1/10 to 1/6 gr.; codeine sulphate, 1/6 to 1/2 gr.; heroin hydrochloride, 1/24 to 1/12 gr.; dilaudid, 1/32 to 1/40; and pantopon, 1/3 gr. The usual medium dose (5 mouse units) of cobra venom was employed. None of the opiates had any appreciable effect on acuity of vision although a slight improvement was occasionally noted after injection of morphine, which in full doses produces myosis in sensitive individuals, but for the most part morphine, dilaudid and pantopon produced no change in acuity of vision and codeine had no effect whatever.

In striking contrast to morphine and other opiates, cobra venom, injected in doses of 5 mouse units, definitely stimulated vision of three fourths of the individuals tested. This increase in acuity ranged from normal V-1 to V-1.5 and occasionally to V-2. The table shows the results obtained with cobra venom in eight individuals and those secured with opiates in four other subjects.

Effect on the Field of Vision

The findings obtained in the perimeter experiments were of even greater interest than those derived from tests of acuity of vision. It was repeatedly found that all the opiates employed—morphine, heroin, codeine, dilaudid and pantopon—definitely decreased or narrowed the field of vision of all the subjects. Other types of analgesics, such as the salicylates, acetanilid, certain barbiturates and amidopyridine, also exerted a similar action. Cobra venom, on the other hand, in nearly every case definitely widened or increased the field of vision. This was true of the field for white but was more marked for the field for blue and still more striking for the fields for red and green. In this respect the drug was in marked contrast to morphine and the other narcotics which, it was found, decreased or narrowed the field of vision in the same order, *i.e.*, white, blue, red and green, the field for green being most affected.

EFFECT OF COBRA VENOM AND OPIATES ON ACUITY OF VISION

Subject	Drug and Dosage Injected	Time Tested in Relation to Injection	Line Seven	Line Eight	Line Nine	Line Ten	Line Eleven
			Meters 7.5 Vision, 0.8	Meters 6 Vision, 1.0	Meters 5 Vision, 1.2	Meters 4 Vision, 1.5	Meters 3 Vision, 2.0
			Read	*Read*	*Read*	*Read*	*Read*
A	Cobra venom 5 m.u.	Before	all	all	1 error	2 errors	none
		After	all	all	all	all	8 out of 9
B	Cobra venom 5 m.u.	Before	all	3 errors	2 errors	5 errors	none
		After	all	all	1 error	1 error	5 out of 9
C	Cobra venom 5 m.u.	Before	all	all	1 error	none	—
		After	all	all	all	3 out of 9	—
D	Cobra venom 5 m.u.	Before	1 error	2 errors	none	—	—
		After	all	all	4 out of 10	—	—
E	Cobra venom 5 m.u.	Before	all	all	2 errors	3 errors	none
		After	all	all	all	all	all but one
F	Cobra venom 5 m.u.	Before	all	all	all	1 error	none
		After	all	all	all	all	4 out of 9
G	Cobra venom 5 m.u.	Before	all	1 error	1 error	2 errors	none
		After	all	all	all	all	6 out of 9
H	Cobra venom 5 m.u.	Before	all	all	all	3 errors	5 errors
		After	all	all	all	all	1 error
I	Morphine, 1/6 gr.	Before	all	all	1 error	1 error	none
		After	all	all	1 error	1 error	none
J	Morphine, 1/8 gr.	Before	all	all	2 errors	all	2 errors
		After	all	all	1 error	1 error	4 errors
K	Dilaudid, 1/40 gr.	Before	all	all	all	all	none
		After	all	all	2 errors	2 errors	none
L	Codeine, 1/2 gr.	Before	all	all	4 errors	none	none
		After	all	1 error	2 errors	none	none

Naturally individual differences occurred. Some subjects were more sensitive to the effects of the drug than others. Quantitatively, however, all the individuals examined revealed similar effects, as the composite charts 1 to 4 plainly demonstrate. In these charts are shown the average figures obtained in 20 normal experiments without drugs, in twelve experiments with cobra venom and in eight experiments with morphine, respectively. It will be seen that the narcotic definitely contracted the field of vision while cobra venom exerted an exactly opposite effect, *i.e.*, widened it. The scope of the respective contractions and expansions of the field of vision for the various colors is shown in charts 2, 3 and 4.

Charts 5 to 8, showing the figures obtained in an experiment on an individual student injected with 1/8 gr. morphine, are a good illustration of the narrowing of the field of vision for all colors. Charts 9 to 12, on the other hand, demonstrate

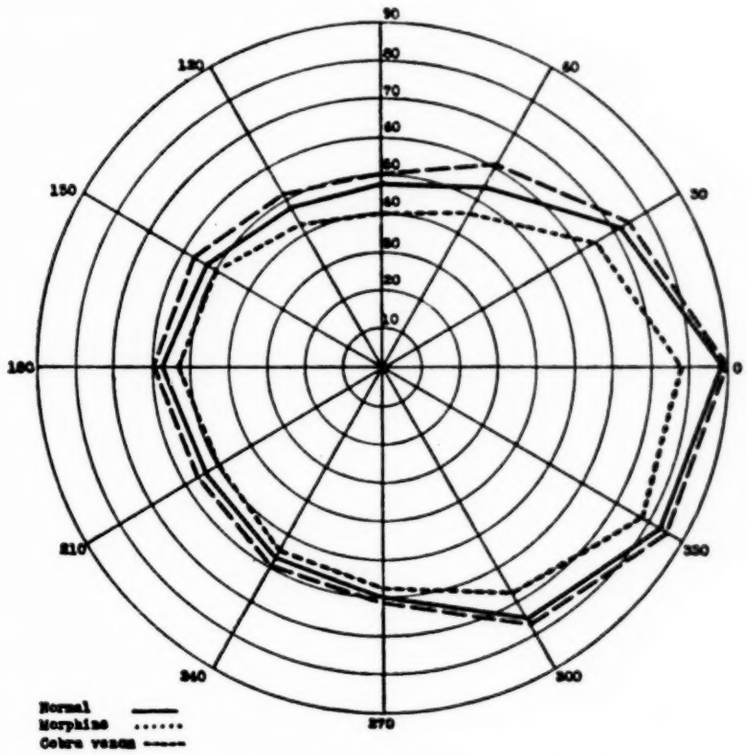

CHART 1. Composite diagram showing averages of 20 normal fields of vision of the right eye for *white*, of 12 after injection of cobra venom, and of 9 after injection of morphine.

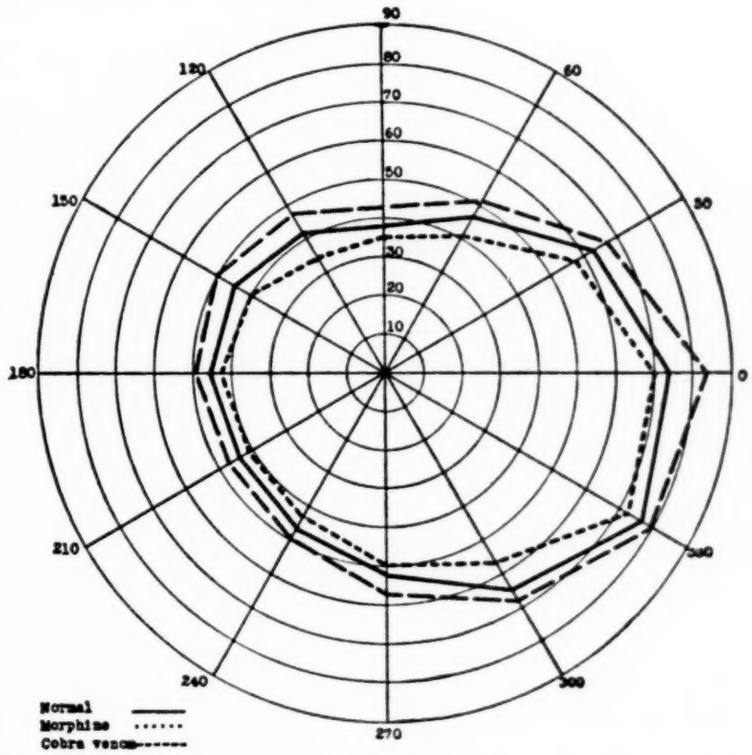

CHART 2. Composite diagram showing averages of 20 normal fields of vision of the right eye for *blue*, of 12 after injection of cobra venom, and of 9 after injection of morphine.

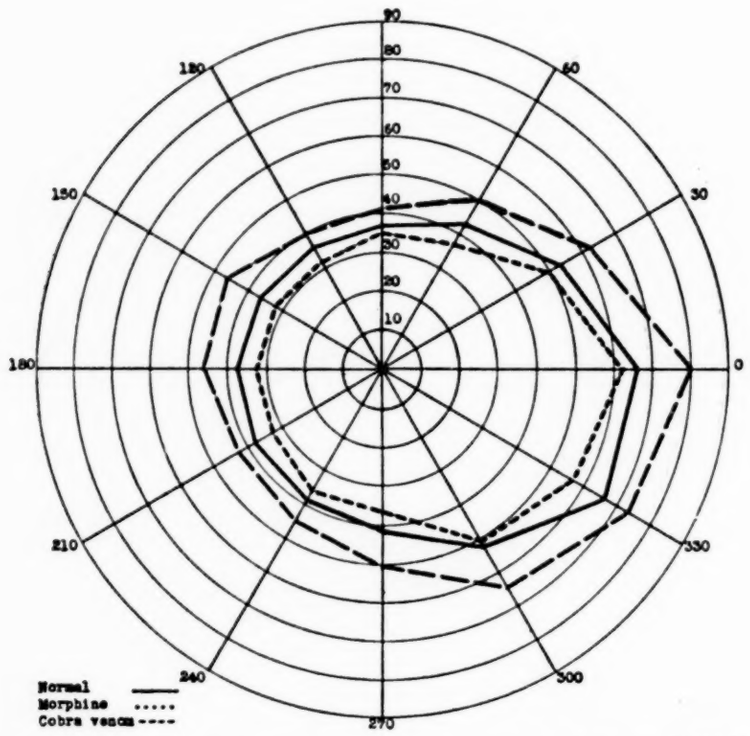

CHART 3. Composite diagram showing averages of 20 normal fields of vision of the right eye for *red*, of 12 after injection of cobra venom, and of 9 after injection of morphine.

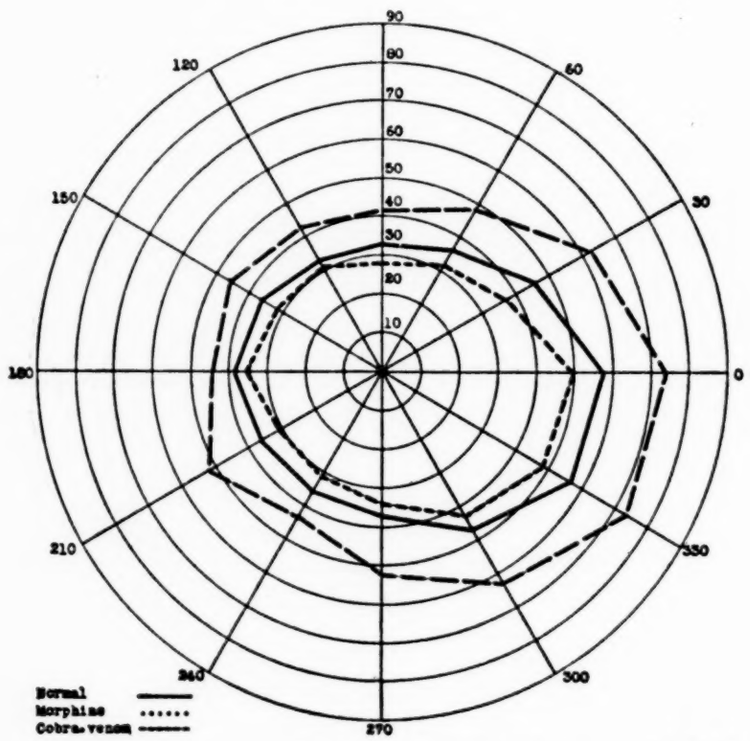

CHART 4. Composite diagram showing averages of 20 normal fields of vision of the right eye for *green*, of 12 after injection of cobra venom, and of 9 after injection of morphine.

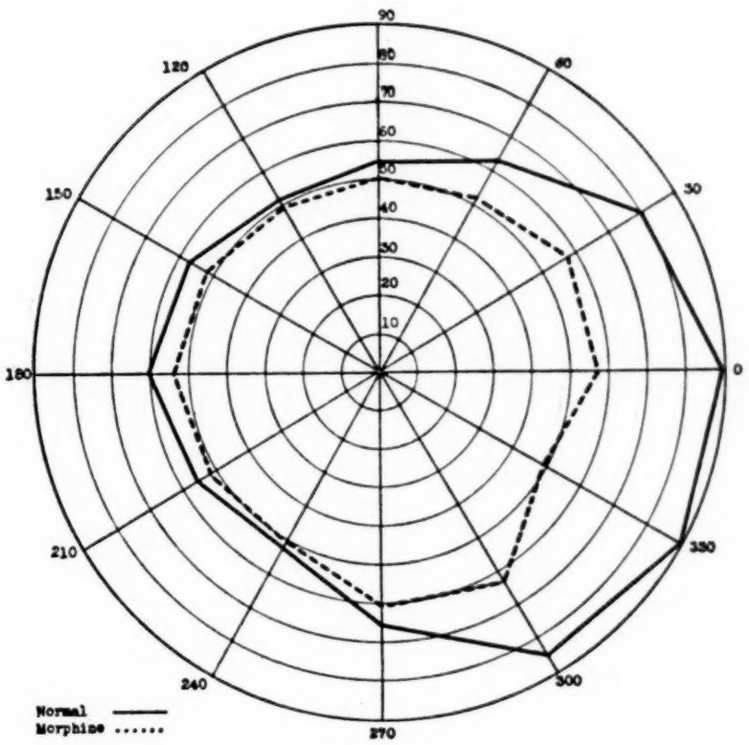

CHART 5. Effect of injection of one tenth grain of morphine on field of vision of A's right eye for *white*.

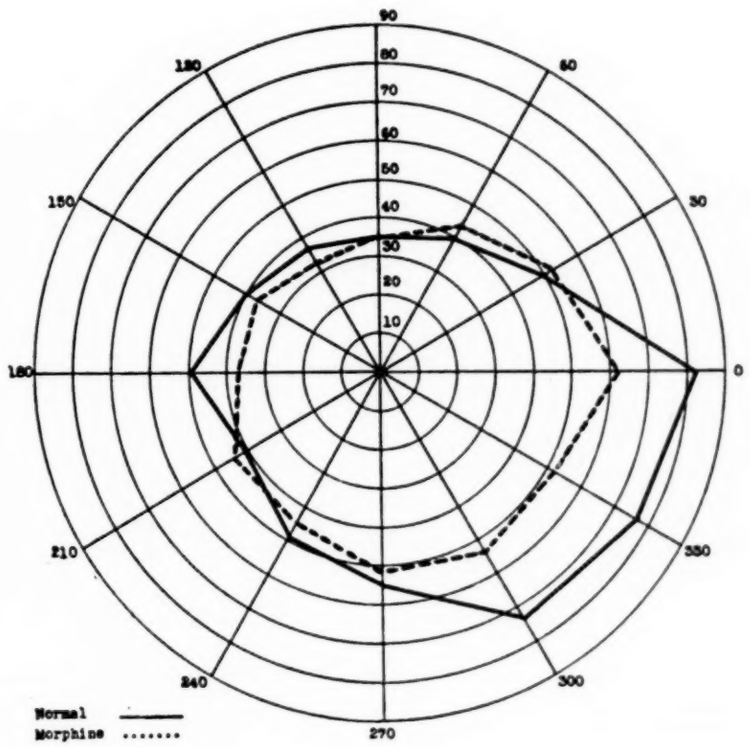

CHART 6. Effect of injection of one tenth grain of morphine on field of vision of A's right eye for *blue*.

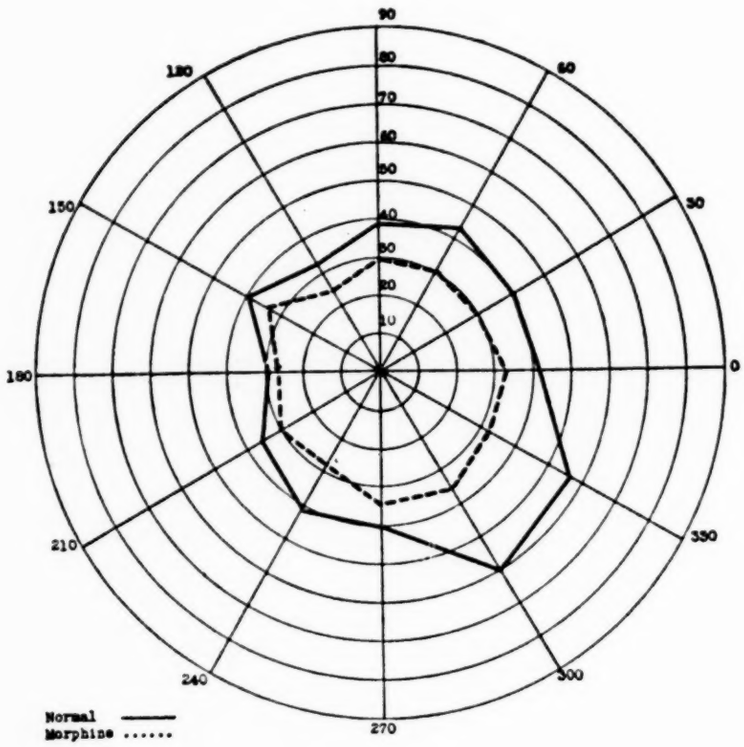

CHART 7. Effect of injection of one tenth grain of morphine on field of vision of A's right eye for *red*.

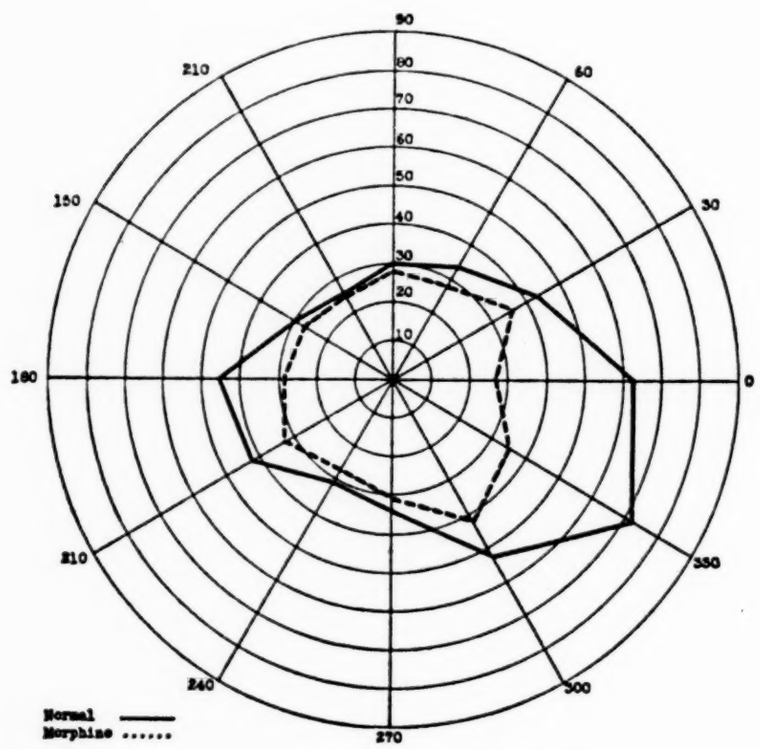

CHART 8. Effect of injection of one tenth grain of morphine on field of vision of A's right eye for *green*.

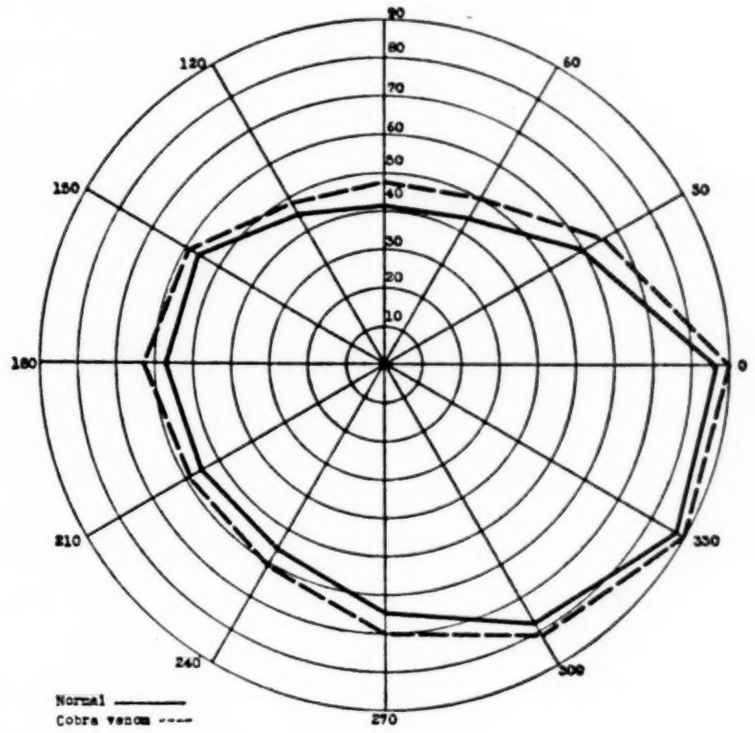

CHART 9. Effect of injection of 5 mouse units of cobra venom on field of vision of B's right eye for *white*.

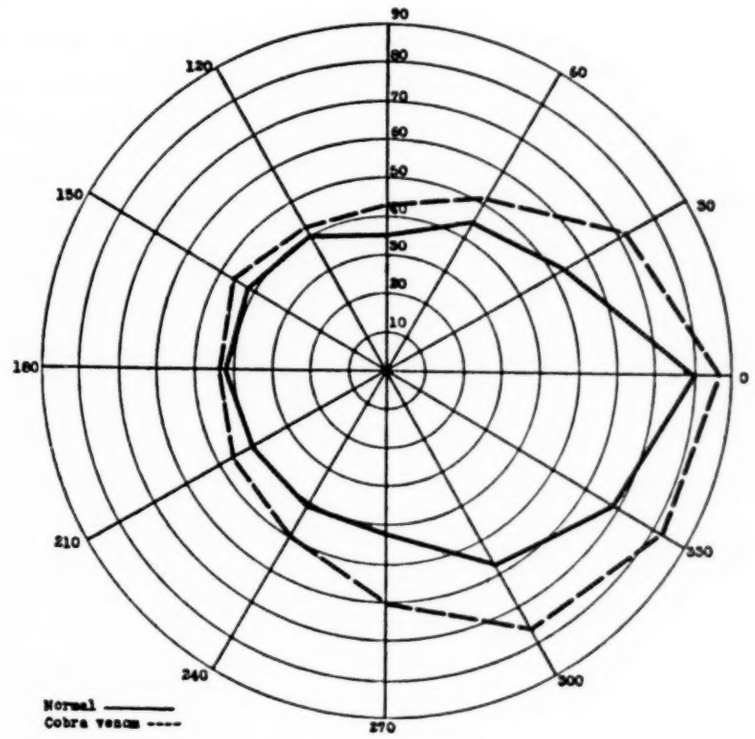

CHART 10. Effect of injection of 5 mouse units of cobra venom on field of vision of B's right eye for *blue*.

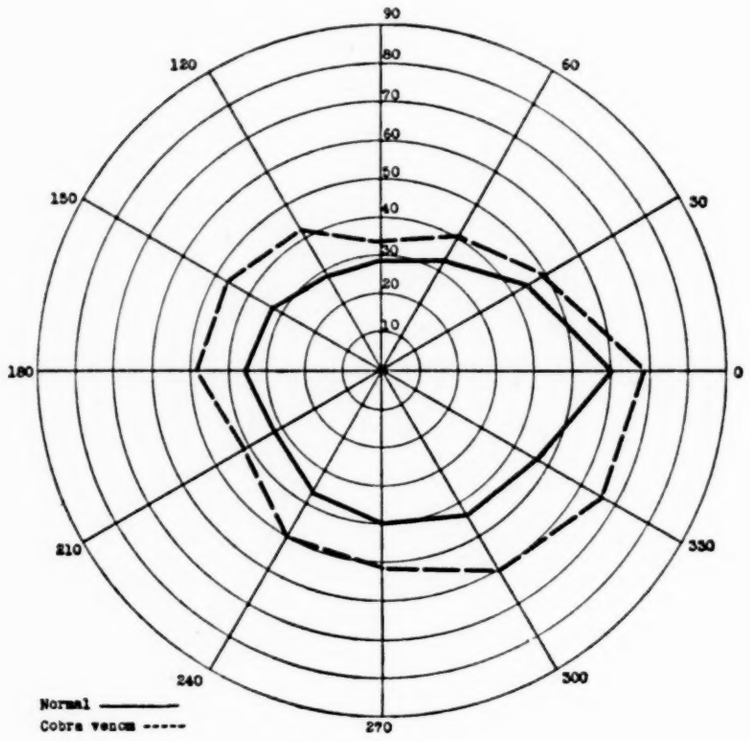

CHART 11. Effect of injection of 5 mouse units of cobra venom on field of vision of B's right eye for *red*.

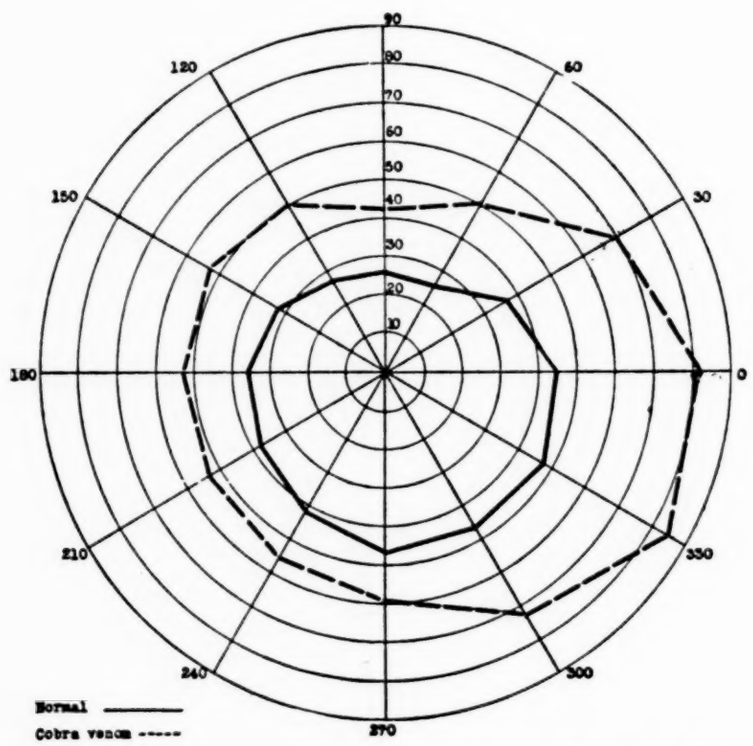

CHART 12. Effect of injection of 5 mouse units of cobra venom on field of vision of B's right eye for *green*.

the effect of cobra venom on another student, who was greatly stimulated by a medium dose (5 mouse units) of the drug.

Discussion

The effect of opium and morphine on the acuity of vision has been the subject of but few experimental investigations. While the mechanism of the marked myosis produced by morphine has been extensively analyzed by physiologists and pharmacologists, clinical tests regarding the effect of opiates on acuity of vision have not been investigated quantitatively and, as far as the writers have been able to ascertain from the literature, studies on the field of vision after administration of narcotics are entirely lacking. It is true that some general statements concerning the effects of the narcotics on vision are to be found in older works. Thus the distinguished pharmacologist, Louis Lewin, in his well-known work on "The Untoward Effects of Drugs," states that morphine and opium may produce amblyopia or amaurosis and ringing of the ears but he adds that very little change in vision is produced by the narcotics in normal people (**14**). The findings of the present writers are therefore of some interest, especially when considered in conjunction with their cobra venom experiments, both with regard to acuity of vision and field of vision. In an interesting work on Indian snake poisons, Dr. Wall, an old physician, describing the picture of fatal cobra bite in human beings, declares that he noted 'no impairment of visual sensation from the time of bite to the moment of death' (**15**). The results of the present writers' experiments not only agree with the empirical findings of Dr. Wall but indicate that therapeutic doses of the drug actually improve acuity of vision. Upon completing their work, the writers found that a similar observation had been made in *pathological* eye cases by the French investigator, Koressios. Koressios, an early enthusiast about cobra venom, and his collaborators describe the effect of injections of this drug on patients suffering from diseases of the retina. They claim that the cobra venom not only improved the general condition of the diseased eyes of such cases but also increased their *acuity* of vision (**16**, **17**).

The findings of the present writers regarding the effect of cobra venom on acuity of vision of normal individuals agree therefore with those obtained by the French clinicians in pathological cases.

A new finding was the observation that cobra venom, while effective in relieving pain through its action on the central nervous elements, produced an effect quite opposite from that of opium on the *field* of vision. While the opiates narrowed or decreased the field of vision, cobra venom widened or increased it in nearly every case. The degree of stimulation effected by cobra venom on the field of vision for the respective colors increased in the following order: white, blue, red and green. The writers are not prepared to offer a full explanation of this difference. Koressios and his collaborators were inclined to ascribe the beneficial effects of the venom to the change which it produced in the retinal circulation. This may well be the case. The studies which the writers are now making on the psychological effects of cobra venom furnish evidence of a directly stimulating action on the brain which must also be considered in connection with the possible influence of the drug on the retinal blood vessels. Perhaps the most remarkable observation made in connection with the present research is the fact that cobra venom in therapeutic doses produces analgesia through its action on some synapse which has to do with the depression of pain but does not affect the special senses, such as vision and audition, nor those cortical areas which have to do with the higher intellectual functions.

Summary

1. The effects of cobra venom and the opiates were studied on the acuity and the field of vision for white, blue, red and green of thirty-five normal individuals.

2. Morphine, codeine, heroin, dilaudid and pantopon definitely contracted or narrowed the field of vision in the following progressive order, white, blue, red and green.

3. Cobra venom has a tendency to increase acuity of vision, and also markedly widens the *field* of vision for the four colors in the following order: white, blue, red and green.

4. This stimulating action of cobra venom on vision may be due in part to an influence on the circulation of the eye and in part to a direct effect of the drug on the brain.

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STUDIES ON THE PSYCHOPHYSIOLOGY OF BOREDOM: PART I. THE EFFECT OF 15 MGS. OF BENZEDRINE SULFATE AND 60 MGS. OF EPHEDRINE HYDROCHLORIDE ON BLOOD PRESSURE, REPORT OF BOREDOM, AND OTHER FACTORS [1, 2]

BY JOSEPH E. BARMACK, Ph.D.

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A theory of McDowall and Wells (4) that the feeling of monotony may be due to an inadequacy of blood circulation for the work being performed, stimulated two researches by the present investigator.

In one of these (1), an attempt was made to find the interrelationships between oxygen consumption, blood pressure, heart rate, subjective ratings (particularly the ratings on a scale of bored-interested), and work output on two tasks expected to be boring, and one task expected to be interesting. Among the results reported in this study, one is of particular relevance to the present investigation. It was found that while physiological changes were closely related to changes in output and feeling tone in a few individual cases, for most subjects this relationship was not sufficiently close to warrant support of the hypothesis of McDowall and Wells that certain peripheral vascular inadequacies are essential to the feeling of monotony. Instead, it was suggested that the feeling of monotony is a result of the operation of more general factors such as the tendency of the subject to revert to a sleep, or sleep-like state during the operation of a task-set. Psychologically interpreted, the cause of this reversion appeared to

[1] The study was performed under the medical supervision of Dr. W. H. McCastline, Columbia University Medical Officer, and members of his staff, to whom I am deeply indebted for their assistance.

[2] I wish to express my gratitude to Dr. A. T. Poffenberger, of Columbia University, whose very generous aid made this study possible.

be the restriction of attention to an inadequately motivated task. The effects of this inadequate motivation become manifest when the dynamic influence of the novelty of the task wears off.

In a second study by the present investigator (**2**), an attempt was made to check on the correctness of an analysis of boredom outlined in the first study. Boredom was described as a state of conflict between the tendency to continue and the tendency to get away from a situation which has become unpleasant principally because of inadequate adjustments to it, resulting from inadequate motivation. The adjustments include all those factors which vary with the sleep-alertness continuum. If the analysis is correct, making the task more strongly motivated, or counteracting the hypnotic trend during 'boring work,' should interfere with the development of a bored attitude to the task. In this second study on 36 subjects, it was found that 10 mgs. of the antihypnotic, benzedrine sulfate, retarded the development of an unfavorable attitude to the task of adding pairs of six-place numbers. In the present investigation, we were interested in finding whether the effects of benzedrine sulfate on the work attitude could be duplicated with another type of repetitive task, such as pursuit-meter operation, and whether other antihypnotics such as 60 mgs. of ephedrine hydrochloride, or a drop in room temperature, or an added financial incentive, would be similarly effective.

The aims of the current investigations, therefore, were to study the possible effects of 15 mgs. of benzedrine sulfate, 60 mgs. of ephedrine hydrochloride, a drop of approximately 10 degrees C. in room temperature, and a financial incentive, on accuracy during two hours of pursuit work, on blood pressure objectively recorded, and on subjective reports on six nine-point scales, of bored-interested, relaxed-strained, irritated-pleased, peppy-fatigued, sleepy-wide awake, attentive-inattentive.

In this paper the effects of 15 mgs. of Benzedrine and 60 mgs. of ephedrine hydrochloride on the above mentioned variables are presented. The effects of the other two factors are reported in the subsequent paper.

Subjects

Ten male graduate students at Columbia University participated in this experiment. Six of them were paid directly for acting as subjects. Four of the ten were remunerated through the N. Y. A. The age range was from 21 to 24.

Procedure

The subjects were first given medical examinations by the medical staff of Columbia University to determine whether they were physically fit for the experiment. Then, to acclimate them to the apparatus and get low resting measures, they visited the Applied Psychology Laboratory at Columbia University for a *preliminary series* of at least nine half-hour sessions. Throughout the entire experiment, the subjects were instructed to have their last meal at least three hours before coming to the laboratory. In the first four of these half-hour sessions, the resting blood pressure and heart rate were recorded three times at ten-minute intervals by means of the Tycos recording sphygmomanometer. During the next four sessions, the three measures during rest were obtained again. A fourth measure was added one minute after the instructions were given to pull on a forty-pound body ergometer fifty times.[3] Following this fourth measurement, the subject did the work. In the ninth and last of this preliminary series, the subjects were given specific instructions on the operation of the pursuitmeter, which was the main task, and went through a short trial period of pursuitmeter work. At the beginning of every main experimental session, the subjects were given a gelatin capsule of a uniform size, color and shape. The capsule contained either 15 mgs. of Benzedrine, 60 mgs. of ephedrine hydrochloride, or placebo. The order of the compounds used was consistent with a prearranged schedule. The order for the control with placebo, cold room with placebo, ephedrine hydrochloride, and Benzedrine, was such for each subject that no condition had a position of advantage. The incentive condition was always last, for special reasons.[4]

After the subject had swallowed the capsule, the sphygmomanometer cuff was adjusted to the non-preferred arm, and the subject was seated in a soft, leather armchair, in front of the Poffenberger pursuitmeter.[5] Final instructions were given to the subject to remain quiet during the half-hour rest period to follow, to fill out the subjective rating sheets accurately at a light-signal, and to work on the pursuitmeter as accurately as possible. The subjective rating sheets were similar to the one reported in a previous study (2) except that the individual scales on them were shifted in successive sheets to minimize a stereotypy of response. Blood pressure was recorded with the Tycos recording sphygmomanometer. The heart rate was determined by

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[3] The purpose of the latter procedure was to find the effect of such an 'aufgabe' on the resting physiology. The results of this experiment will be incorporated in another paper.

[4] Mainly to avoid a possible carry-over of the effects of the incentive to the subsequent conditions.

[5] Essentially, the Poffenberger pursuitmeter consists of a table, on the top and in the central and distal end of which are two pointer arms. The standard which points down is moved irregularly back and forth by a motor and eccentric pulley arrangement. The variable which points up is to be aligned with the standard pointer. By means of a brush and commutator-like device attached to the pointer arms and a battery of electrical counters, a record is obtainable of the displacements of the variable from the standard.

clocking 25 pulsations. The obtained figure was interpolated to read beats per minute. The procedure for each of the main experiments (except the incentive experiment) from this point was as follows:

1. During the half-hour rest period, blood pressure and heart rate were each measured three times at ten-minute intervals. These measurements were made behind a one-way light screen.

2. At the end of the third measurement, the subject was signalled, whereupon he filled out the first subjective rating sheet, turned it over face down, and, without any further instructions, immediately began to operate the pursuitmeter for an accurately timed fifteen-minute interval.

3. During the fifteen-minute work period, and without stopping the work, vascular measures were taken twice, the first after five minutes, and the second after ten minutes of work. The two readings were averaged.

4. At the end of the fifteen-minute period, the subject was signalled, he stopped the pursuit work and filled out the next subjective rating sheet while the experimenter recorded the pursuit performance for that period. As soon as the subject finished filling out the rating sheet, he was signalled again to resume the pursuit work.

5. The entire process was repeated until the subject had completed the eight fifteen-minute periods of work of the particular session.

We experienced difficulty in pegging accurately the diastolic pressure with the Tycos recording sphygmomanometer. For this reason, the measure is not regarded as reliable, and is neglected in the discussion of the results.

Results

The essential data are presented in Fig. 1. In determining the reliability of the obtained mean differences, Fisher's method (3) for testing the significance of the differences of the means of small samples was used. For each variable studied, 8 or 9 sets of measures are presented for each two and one-half hour experimental session. In view of the fact that the measures shift in any one experimental session, an average of all the measures of a single variable for a given session would be meaningless. For this reason, in discussing the reliability of the differences between the means of, for example, Benzedrine and placebo systolic pressures, reference is made to the means at representative or meaningful periods of the two-hour work session. Although each of these mean differences may not satisfy Fisher's criterion of significance, certain consistent differences may be considered as significant. It is intrinsic to the form in which the data appear that the significance or lack of significance in some cases becomes a function of the judgment of the interpreter. Duplicate measures on a single subject which tend in the same direction are of

value in minimizing the role of chance as a factor in their interpretation. However, they do not affect the role of chance in the selection of subjects. Therefore, to permit the reader to evaluate the significance of the data, Fisher's p values (chances in 100 that so large a difference between the two means is due to chance) are presented for differences at key

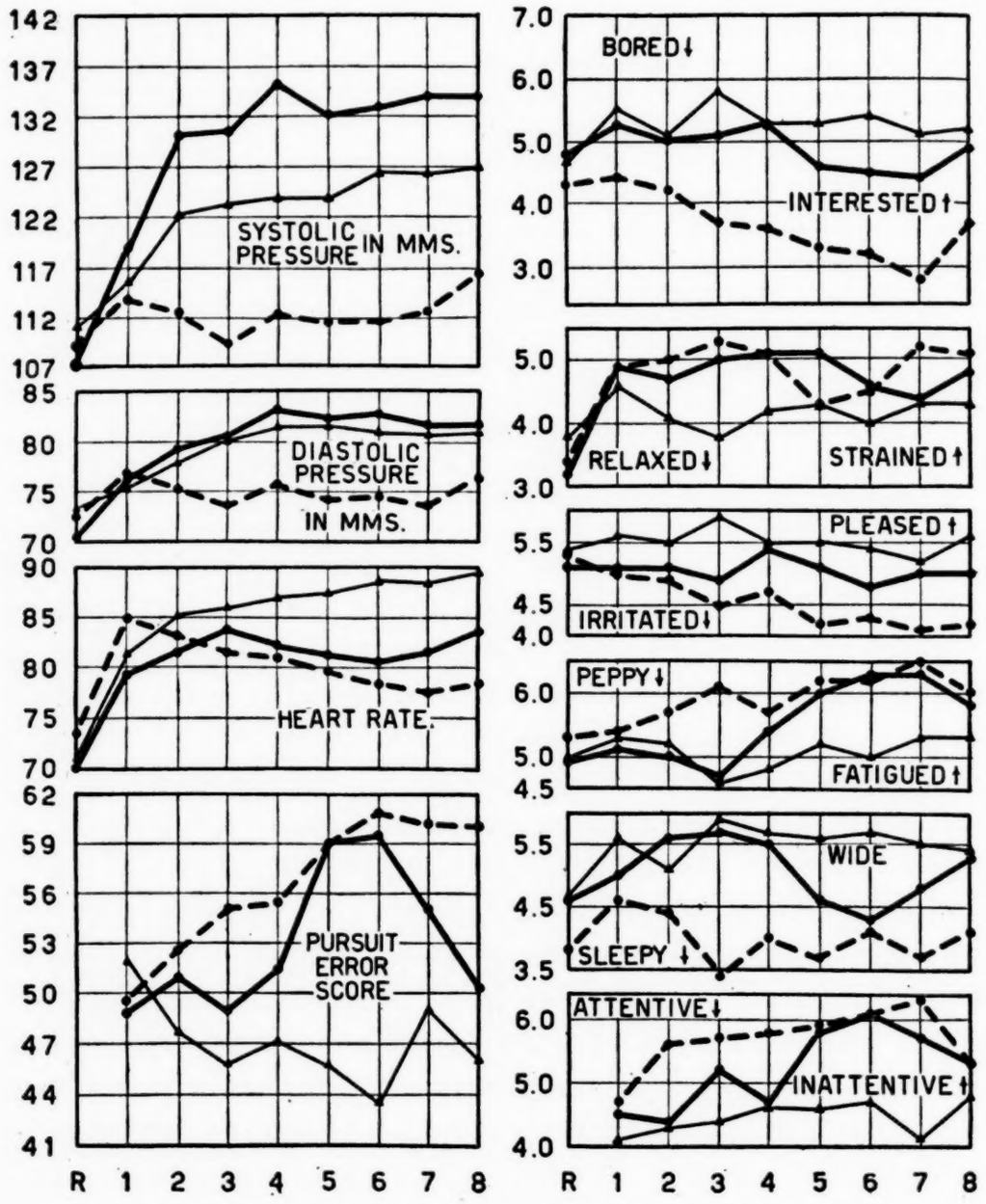

FIG. 1. The thin continuous line represents the Benzedrine condition. The heavy continuous line represents the ephedrine conditions. The broken line represents the placebo condition. *R* represents a thirty-minute rest period. 1, 2, 3, etc., represent successive 15-minute pursuit activity periods. Arrows indicate the direction of increase on the subjective rating scales.

periods. Where the p value is *less* than 1, t[6] values are presented.

A. The Effects of 15 mgs. of Benzedrine Sulfate on the Factors Studied

1. *Systolic Pressure.*—The Benzedrine administered in a gelatin capsule achieves its optimal effect on systolic blood pressure within approximately one hour. The differences in systolic pressure between the Benzedrine and control conditions for the remaining work periods are of the order of 12 mms of mercury. The t values for these differences are at the third period, 3.3, at the seventh period, 4.5, and at the eighth period, 3.5. The pressor effect of the 15 mgs. of Benzedrine is clearly indicated by the data under the conditions of the experiment.

2. *Heart Rate.*—The mean differences in heart rate between the Benzedrine and control conditions are of the order of five beats per minute, one hour after the administration of the capsule. The t value for the difference of the means at the seventh period is 4.4, and at the eighth period, 5.1. Under the conditions of the experiment, the cardioaccelerating effect of the 15 mgs. of Benzedrine is also clearly demonstrated.

3. *Pursuit Error Score.*—Under the influence of the 15 mgs. of Benzedrine, pursuit accuracy increases slightly, whereas with the placebo, the performance become progressively inaccurate. The p value for the difference between the two mean error scores at the sixth period is 8, at the seventh period, 27, and at the eighth period, 11. While these values are too high to regard the differences at individual periods as significant, there are reasons for so regarding the differences of a series of periods. Firstly, the trend of the differences is one of increasing dispersion. Secondly, the *critical ratio* for the difference in error score between the averages for the Benzedrine and placebo of the sixth, seventh and eighth periods combined is 4.7. Thirdly, one subject, despite the Benzedrine, fell asleep for a good part of the seventh period,

[6] The t value corresponds to a critical ratio. For the number of degrees of freedom here available (9), when t equals 3.25 or better, the chances in 100 that so large a difference as the one obtained may be due to chance are 1 or less.

raising his error score from 65.4 in the sixth, to 104.1. This increase accounts for the unusually high *p* value reported for the error score difference at the seventh period. The foregoing reasons warrant the conclusion that under the conditions of the experiment, the 15 mgs. of Benzedrine arrested the development of pursuitmeter inaccuracy.

4. *Report of Boredom.*—The data demonstrate clearly that the 15 mgs. of Benzedrine prevented the development of that condition which would have resulted in a report of boredom. The *p* value for the mean difference in rating at the third period is 1.5; the *t* value at the seventh period is 3.8, and the *p* value at the eighth period is 3.

5. *Report of Strain.*—The effect of the Benzedrine on the report of relaxed-strained is not clearly indicated by the *trend* of the data. There is a suggestion, however, that the Benzedrine prevents the development of a feeling of strain under the conditions of the experiment. The *p* value for the mean difference in rating at the third period is 1.5, and at the eighth period, 19.0.

6. *Report of Irritation.*—The mean differences in the rating on the scale of irritated-pleased between the Benzedrine and placebo conditions suggest that the Benzedrine prevents the development of a feeling of irritation. The *p* value for the mean difference in rating at the third period is 1, at the seventh period, 7, and at the eighth period, 3.

7. *Report of Fatigue.*—The mean differences in ratings on the peppy-fatigued scale suggest that the Benzedrine prevented the development of a feeling of fatigue under the conditions of the experiment. The *t* value of the mean difference at the third period is 4.4. The *p* value of the mean difference at the seventh period is 6, and at the eighth period, 25.

8. *Report of Sleepiness.*—The antihypnotic effect of the 15 mgs. of Benzedrine is reflected in the mean differences in ratings on the sleepy-wide awake scale. The *p* values at the third, seventh, and eighth periods are 1, 2, and 8, respectively.

9. *Report of Attention.*—The data suggest that the subjects felt their attention to the task was better sustained under the Benzedrine than under the placebo condition. The *p*

values for the differences at the third, seventh, and eighth periods are 9, 1, and 40 respectively.

Summary on the Effects of the 15 mgs. of Benzedrine.—In many instances, statistical tests of the significance of differences between the measures of the Benzedrine and the control condition at specific periods are not satisfactorily met. Nevertheless, in the judgment of the writer, the trends of the repeated measures give the differences a high degree of reliability, with the exception of those obtained on the relaxed-strained scale. The data therefore permit the conclusion that the 15 mgs. of benzedrine sulfate increase the systolic blood pressure and heart rate, and prevent the development of a bored attitude to the repetitive pursuit task as manifested by sustained pursuitmeter accuracy and 'favorable' ratings on a series of subjective rating scales.

B. The Effects of 60 mgs. of Ephedrine Hydrochloride on the Factors Studied

1. *Systolic Pressure.*—The ephedrine hydrochloride had a marked pressor effect (see Fig. 1). The *t* values for the differences in mean pressure between the ephedrine and placebo conditions at the third, seventh, and eighth periods are 6.3, 6.1, and 3.6, respectively.

2. *Heart Rate.*—The effect of the drug on the heart rate under the conditions of the experiment is negligible.

3. *Pursuit Score.*—The effect of the ephedrine on pursuit accuracy is peculiar. Initially, the tendency is to sustain accuracy of performance; this tendency is followed by a sharp drop in accuracy in the fifth and sixth periods, and then by an improvement toward the end. This depression might be considered an artifact were it not for analogous changes indicated in most of the subjective ratings for the corresponding periods. The *p* value for the mean difference between the ephedrine and placebo pursuit scores at the third period is 25, and at the eighth period, 3. Nevertheless, the average pursuit error scores under ephedrine do not exceed those under the control condition. In sum, two results are of interest; first, the 60 mgs. of ephedrine hydrochloride tend to

sustain pursuit accuracy initially, and second, that one and one-half hours after its administration in capsule form, a depression in accuracy occurs for the duration of half an hour. That the depression is no artifact is indicated by certain parallel, subjective rating changes.

4. *Report of Boredom.*—The average ratings on the bored-interested scale under ephedrine hydrochloride follow closely those of the Benzedrine except in the fifth, sixth, and seventh periods, when the ephedrine appears to be slightly less effective. The *p* value for the mean difference between the ephedrine and control condition at the third period is 4, at the seventh period, 3, and at the eighth period, 8.

5. *Report of Strain.*—There are no consistent differences in the averages of the ratings on the relaxed-strained scale between the ephedrine and placebo conditions.

6. *Report of Irritation.*—The effect of the ephedrine on the reports of irritated-pleased is slight and consistent, but it is less than for the 15 mgs. of Benzedrine.

7. *Report of Fatigue.*—The changes in report on the peppy-fatigue scale under ephedrine are of interest. The maximum stimulating effect of ephedrine is reached in the third period where the *p* value of the mean difference between the ephedrine and control conditions is 2. Thereafter the effect on this scale is negligible.

8. *Report of Sleepiness.*—The effect of the ephedrine on the report of alertness is similar to that on the peppy-fatigued scale. The maximum effect is reached in the third period. The *t* value for the difference between the ephedrine and placebo averages at that period is 3.4. The reports shift to sleepiness in the fifth and sixth periods. A rise towards alertness occurs in the seventh and eighth periods. The *p* values for the mean differences at the seventh and eighth periods are 5 and 4 respectively.

9. *Report of Attention.*—The effect of the ephedrine on the report on the attentive-inattentive scale is manifest only in the early part of the work session. The *p* values for the mean differences at the second, third, and fourth periods are 5, 50 and 8, respectively.

In sum, under the conditions of the experiment, the 60 mgs. of ephedrine hydrochloride have a marked stimulating effect on the systolic pressure but a negligible effect on the heart rate. The pursuitmeter and subjective rating data *suggest* that initially the ephedrine retards the development of an unfavorable attitude to the repetitive pursuit work. However, approximately one and one-half hours after the administration of the drug, an alteration occurs in this tendency, giving rise to a relative depression in pursuit accuracy and most subjective reports. A recovery in the last half-hour follows the depression, according to some of the indices used. No systolic blood pressure or heart rate changes parallel the obtained depression. Here again, as with the Benzedrine, statistical tests for the significance of mean differences at individual periods are not satisfactorily met in many instances. But, in the judgment of the investigator, the data assume significance by their internal consistency.

C. A Comparison of the Effects of 15 mgs. of Benzedrine and 60 mgs. of Ephedrine Hydrochloride

1. *Vascular Effects.*—The 60 mgs. of ephedrine hydrochloride have a superior pressor effect than the 15 mgs. of banzedrine sulfate. However, the 15 mgs. of Benzedrine are more effective in accelerating the heart rate.

2. *Pursuit Performance and Subjective Ratings.*—A comparison of the two drugs with regard to pursuit accuracy and subjective ratings is made difficult by the peculiar alteration which occurs in the effects of the 60 mgs. of ephedrine hydrochloride approximately one and one-half hours after its administration. One definite conclusion is permitted, however. The 60 mgs. of ephedrine hydrochloride is not *more* effective, but is, if anything, *less* effective than the 15 mgs. of Benzedrine in counteracting the monotonous influence of the task.

Discussion

The results of the present investigation on the effects of 15 mgs. of Benzedrine confirm a previous finding (**2**) with 10 mgs. of the same compound, that it retards the development of an unfavorable attitude to a repetitive task.

The course of some of the effects of the 60 mgs. of ephedrine is peculiar. Approximately one hour after its administration, the ephedrine influences pursuit accuracy and subjective ratings almost as effectively as the 15 mgs. of Benzedrine. The stimulation lasts for approximately one-half hour, but thereafter a depression in pursuit accuracy and in 'feeling tone' occurs which has no counterpart in the vascular measures used. There is an uncertain indication according to some of the psychological measures that the stimulating influence of the ephedrine is restored in the succeeding half-hour of pursuit effort. This peculiar course of the effects of the ephedrine is of twofold significance. First, it demonstrates within a single session, the possible independent variation of 'feeling tone' and work output on the one hand, and systolic blood pressure and heart rate on the other. Secondly, it points to the necessity of studying the psychological effects of drugs for a continuous, long period just as their physiological effects are usually so studied. The fact that the physiological effects of a drug run a consistent course is no guarantee that the psychological effects will also be consistent.

Summary and Conclusions

The effects of 15 mgs. of benzedrine sulfate and 60 mgs. of ephedrine hydrochloride were compared with those of a control pill with regard to systolic blood pressure (objectively recorded), heart-rate, pursuitmeter accuracy, and subjective ratings on a nine-point scale of bored-interested, relaxed-strained, irritated-pleased, peppy-fatigued, sleepy-wide awake, and attentive-inattentive. Ten apparatus acclimated subjects participated in this experiment. The main findings under the conditions of the experiment are as follows:

1. The 15 mgs. of Benzedrine *retarded* the development of:

a. Pursuit inaccuracy,

b. A condition leading to a report of boredom, of irritation with the work, of fatigue, of sleepiness, and of inattention.

2. The 15 mgs. of Benzedrine increased the systolic blood pressure and the heart rate.

3. The 60 mgs. of ephedrine hydrochloride had a similar, though weaker and more transient, effect on pursuit accuracy and on the subjective ratings.

4. The 60 mgs. of ephedrine hydrochloride had a more pronounced effect on the systolic pressure than the 15 mgs. of Benzedrine, but was practically without effect on the heart rate.

5. A peculiar depression in the 'sustaining' effect of the ephedrine is obtained on most of the psychological measures used. This depression has no correlate in the systolic pressure or in the heart rate changes.

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A SPACED ORDER OF MERIT FOR PREFERENCE JUDGMENTS [1]

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The method of rank order, or order of merit, has long been used for the study of the preferences of individuals for material presented to them, as well as for psycho-physical measurements. We are concerned in this article with a study of the result and the possible values of a change from its usual form.

It is apparent that the rank order method is not a flexible one for the subject. The items must be arranged solely in a serial order, ranging from the best liked specimen, when we are dealing with preferences, to the one least liked. There is no allowance for the expression of relative differences in preference for specimens in this type of order, if the subject were prepared to make them. Two specimens might be evaluated very similarly and yet quite differently from a third, which one might be considerably less liked, let us say, than the second in order, yet the subject can only arrange them in one, two, three order. There is no possibility for the subject to express these inter-specimen differences. Moreover, it is not possible for the subject to indicate that two specimens are equal in his estimation since tied ranks are not allowed.

The following experiment was carried out with a variation of the usual rank order method in that the subject was given an opportunity to alter rank order through the use of tied ranks and variable spacing between the specimens. The method in effect allows the subject to set up his own continuum from 'best liked' to 'least liked' and to arrange the specimens along it according to the evaluative feelings they

[1] This experiment was conducted in the Psychological Laboratory of the University of California under Professor Warner Brown, to whom the author is indebted for helpfu criticism and suggestions.

evoke. There was no restriction on the ways in which the specimens could be grouped or arranged and tied ranks were allowed if the subject wished to array the specimens in that manner.

Our primary interest is the extent to which the subjects utilized the possibilities of expressing judgments through the variable spacing of the specimens along the continuum, and in what manner they arrayed the items. If these possibilities of expressing nuances of comparative liking or disliking through such discriminative spacing were widely utilized by the subjects it would indicate that a real need for such possibilities existed and that the usual rank order method is restrictive is not permitting full expression of differences in evaluation.

Moreover, if the potentialities of this type of arrangement are taken advantage of by a group of subjects in judging material this technique would possibly prove a more satisfactory basis for the determination of the group's preference than other methods. These use as raw data the individual ranked order of specimens and some, such as Thurstone's 'law of comparative judgment' (1) arrive at scale values for the items expressing the group preference. The technique proposed here, however, that allows the subjects to 'scale' their own judgments along a continuum and then combined these individual scalings into one for the group would require fewer statistical transformations and would be simpler and more direct.

Experiments in the past on the preferences of individuals for materials such as colors and color combinations, geometrical forms, lines, and objects of art, have revealed considerable disagreement between the judgments of the participating individuals. That which is best liked by one subject may be thoroughly disliked by another, or a matter of indifference to a third. Lack of agreement seems to be the rule in all such experiments to the despair of experimenters.

If it turns out that the methods used in these experiments, generally the order of merit, were restrictive and did not allow adequate expressions of the preferences of the subjects,

we might expect that techniques more flexible and adapted to expressing whatever relative differences in judgments the subjects experienced might reveal more agreement between individuals, and a clearer picture might result of the extent and nature of the disagreements.

Subjects, Materials and Instructions

The subjects were 98 sophomore and junior year college women students from an introductory class in psychology.

The materials were in two sets of ten specimens. One set, geometrical forms, were simple solid shapes, bounded by straight lines, cut out of dark blue dull-surfaced paper and mounted on white cardboard cards 3 × 4 inches in size. The other set, compositions of individual saints with scrolls and their characteristic attributes (hereafter called 'saints' for convenience) were old German engravings of simple lines with little shading. One saint was depicted in each composition. They differed from each other in the position of the body, the arrangement of the garments, facial expressions, and general organization of saint, scroll, and attribute. These were on cards 5 × 4 inches in size.

The experimenter stood beside the subject before a large table. The instructions were as follows:

> "Here are ten geometrical forms. Look them over carefully and pick out the one you like best of all and put it at this end of the table. Then pick out the one you like least of all and place at the other end. Then arrange the others inbetween these two in the order of your preference for them.
>
> "If arranging these forms to show your preferences for them, there are several things you can do. If you feel the same way about two specimens you can put them in the same place. This would mean that you judged them alike and did not like or dislike one more than the other. Another thing you can do is to let the spaces between the forms indicate the differences in your feelings for them. If two forms are placed closely together it would show that they appeal to you in about the same degree. If they are widely separated, it would mean than you judge them quite differently and one is liked much more than the other. Thus the way in which you arrange the specimens along the table, whether they are close together or far apart will show the differences in your feelings for them. Is this clear?
>
> "You can use as much of the table as you want or as little. You can arrange the cards in any way whatsoever to express your judgments. This is not a test of any sort. Just arrange the specimens to show as well as you can your preferences for them."

When the forms had been arranged and their positions recorded by the experimenter, the saints were given to the subjects without further instructions. They were placed on the table before the subjects in a haphazard order.

Experimental Results

Examination of the arrays of specimens reveals that the subjects reacted in a number of different ways to the instruc-

tions as shown by the manner in which they arranged the items to express their judgments. Table I gives a list of the various kinds of arrays and their frequency of occurrence for both sets of specimens.

TABLE I

FREQUENCY OF OCCURRENCE OF TYPES OF ARRAYS

Type of Arrangement	Forms		Saints	
1. Regular spacing, no grouping	0	0%	5	5.4%
2. Regular spacing, tied ranks	5	5.1	8	8.7
3. Semi-regular spacing, no grouping	3	3.0	9	9.8
4. Variable spacing, no grouping	8	8.2	5	5.4
5. Variable spacing, grouping	82	83.7	65	70.7
a. Ties only	12	14.6%	15	23.1%
b. Couplings only	35	42.7	23	35.4
c. Ties and couplings	35	42.7	27	41.5
	82	100.0%	65	100.0%
Grand total	98	100.0%	92*	100.0%

* Six subjects could not rank these preferentially.

Some subjects did not accept the opportunities of the instructions and in the regularly spaced arrangement of specimens virtually resorted to simple rank order (Type No. 1). This manner of arrangement was the least frequent of all and did not occur with the forms. In practically all of these arrays the items were placed touching one another, forming a continuous unbroken band, and presented a decided contrast to the variably spaced arrangements. Some subjects utilized the possibility of tied ranks (Type No. 2) in this regularly spaced disposition of items, but to a limited extent as there was only one tie of over two specimens and only three arrays had two ties.

The third type of array includes those in which the items were generally spaced at regular intervals but either showed a slight irregularity throughout or broke the regularity in the disposition of one specimen at a much wider interval than was maintained throughout the rest of the order. As with the first two types, the specimens were generally placed immediately beside one another, or at small distances. We have classified these arrays apart from the variably spaced ones, since the regularity of ordering was a prominent characteristic

and the appearance of these arrays was quite distinct from that of the variably spaced ones.

The majority of the subjects took advantage of the instructions and arranged the specimens at varying distances from one another (Types No. 4 and 5). 91.9 percent of the form arrays are of this type, and 76.1 percent of the saint arrays. The majority of these arrangements (Type No. 5) also reveal the use of tied values and the grouping of specimens together in a cluster. However, a number of variably spaced orders did not use either tied ranks or groupings (Type No. 4).

Ties in position occurred in both regularly and variably spaced arrangements and for all types of arrays are found in 53.0 percent of the form orders and 54.3 percent of the saint. Two or more specimens would be placed at the same positions and adjacent to each other at right angles to the right-left line of items.

We have referred to the grouping of specimens together into a cluster. This phenomenon, which we call coupling, was the frequent placing of a number of items horizontally in order along the table and touching one another laterally. If not actually touching they were considered as a coupling when disposed so closely that they formed a group in themselves apart from the other specimens. In many cases the subject indicated that they were to be considered as a group. Specimens were arranged thus apparently when a minimum of difference distinguished them. The frequency of occurrence of this phenomenon led us to distinguish those arrays evincing it. We will present below an analysis of its occurrence and that of ties.

Space does not permit the presentation of the complete records of the variably spaced orders. The specimens were arranged along the table at varying distance, some in isolation, others in ties or grouped together into couplings. The distances which separated the specimens varied considerable in size. Few inter-specimen distances were over twelve inches and the most frequent distance was between six and eight inches.

The total lengths of the orders varied from a minimum of 28 inches to a maximum of 81 inches for the forms, with a median length of 51.5 inches. For the saint arrays, the range was from 25 inches to 85 inches with a median length of 46 inches. Arrays without ties were generally longer than those with them.

Analysis of Ties

We now turn to an analysis of the ties in the variably spaced arrays. As shown in Table I, ties were found in the arrays of forty-seven, or 67.3 percent, of the forms and in forty-two, or 64.6 percent, of the saints. Seventy-four ties are found in the form arrays and seventy-three in the saints.

Ties did not occur with equal frequency at all positions. As shown in Table II ties involved form specimens in positions 2, 3, and 7, 8, and 9 more frequently than those first, last, and in positions 4, 5, and 6. With the saints, ties involved items considerably more frequently at positions lower in the order of preference than near first place.

TABLE II

Frequency with Which Specimens at Each Position were Involved in a Tie

Specimens	Position*									
	1	2	3	4	5	6	7	8	9	10
Forms.....	9	27	17	12	11	13	21	28	24	8
Saints.....	4	8	14	20	19	21	25	24	29	20

* 1 is first, or 'most liked,' specimen.

There were differences between ties in the number of specimens they involved. The following table shows for both sets of specimens the frequency of ties of two, three, or more items.

The subjects differed widely in the number of ties they made and the number of specimens that were included in them. While some arrays had only one tie of two items, some orders had two or three ties each involving two, or three, or sometimes four specimens. The following table shows the frequency with which arrays having ties occurred on the basis

TABLE III

FREQUENCY OF OCCURRENCE OF TIES OF TWO, THREE, OR MORE SPECIMENS

Number of Items in Tie	Forms		Saints	
2	61	82.4%	52	71.2%
3	12	16.2	13	17.8
4	1	1.4	4	5.5
5			1	1.4
6			1	1.4
7			2	2.7
Total:	74	100.0%	73	100.0%

of the number of ties in the array and the number of specimens involved in them.

TABLE IV

FREQUENCY OF ARRAYS BY NUMBER AND MEMBERSHIP OF TIES

Arrays Classified by Frequency and Membership of Ties	Forms		Saints	
1 tie of 2 specimens	20	42.6%	9	21.4%
2 ties of 2 specimens each	12	25.5	9	21.4
3 ties of 2 specimens each	4	8.5	6	14.3
1 tie of 3 specimens	5	10.6	5	11.9
2 ties of 3 specimens each	2	4.3	1	2.4
1 tie of 4 specimens	1	2.1	2	4.8
2 or 3 ties of 2, 3, or more specimens in each	3	6.4	10	23.8
Total	47	100.0%	42	100.0%

Considering Table IV from the standpoint merely of the number of arrays exhibiting only one tie, or only two ties, and so on, gives the information of Table V.

TABLE V

FREQUENCY OF ARRAYS BY NUMBER OF TIES ONLY

Arrays Classified by Frequency of Ties only	Forms		Saints	
1 tie only	26	55.3%	20	47.6%
2 ties	16	34.1	13	31.0
3 ties	5	10.6	9	21.4
Total	47	100.0%	42	100.0%

To sum up the analysis of the placing of specimens in ties. For both sets of specimens approximately one-half of the arrays of all types showed tied specimens, 53.0 percent of

the forms, 54.3 percent of the saints. Of those arrays with variably spaced specimens (Type No. 5) between one-half and two-thirds had one or more ties: 57.3 percent of the forms, 64.6 percent of the saints. Of the arrays with ties one-half had only one tie, 55.3 percent for the forms, and 47.6 percent for the saints. There was a tendency for the forms not to be placed in ties around the first and last positions and in the middle of the order. This was not true of the saint specimens orders which showed many more ties in the less liked range than in the more preferred. For both sets of specimens the majority of ties were of only two members.

Some differences between the ways in which the two sets were arranged are found in the frequency of occurrence of multimembered ties and of arrays having ties of various degrees of complexity. Although, as mentioned above, the majority of ties in both sets were of two items only (Table III), of the ties in the form orders only one, or 1.4 percent, had four specimens and there were none with more, while of the ties in the saint orders eight, or 11.0 percent, were of four specimens or more; two ties in fact had seven specimens. And as Table IV shows, while almost one-half of the arrays of forms had only one tie of two items each, one-fifth of the saint arrays were of this sort and there were more arrays of these specimens in which several ties each involved several specimens. The saint orders thus had more ties involving more specimens than were present in the arrays of the forms.

Analysis of Couplings

Specimens were more frequently grouped together in a coupling than were placed in tied positions. In the arrays of Type No. 5 there was a total of 136 couplings in 70, or 85.4 percent of the form arrays and a total of 98 couplings in 50, or 76.9 percent of the saint orders.

For both sets of specimens there appeared to be a slight tendency for subjects to place items in coupled groups at the preferred end of the order. There is a rather constant decrease in frequency from the preferred to the least preferred specimen.

TABLE VI

FREQUENCY WITH WHICH SPECIMENS AT EACH POSITION WERE INCLUDED IN A COUPLING

Specimens	Position									
	1	2	3	4	5	6	7	8	9	10
Forms....	29	45	43	37	40	40	37	32	28	21
Saints.....	24	31	32	28	28	30	27	30	28	19

As with the ties, the majority of such groupings included only two or three specimens. Table VII gives the frequency with which couplings of two, three, or more specimens occurred. Some differences were apparent between the two sets of specimens in that while some couplings in the form arrays were of six specimens and there were none of this magnitude in the saint orders, the latter specimens had relatively twice as many such groupings which included more than two items.

TABLE VII

FREQUENCY OF OCCURRENCE OF COUPLINGS OF TWO, THREE OR MORE SPECIMENS

Number of Items in Coupling	Forms		Saints	
2	96	70.6%	47	48.0%
3	30	22.0	37	37.8
4	7	5.2	11	11.2
5	1	.7	3	3.0
6	2	1.5		
	136	100.0%	98	100.0%

While about one-half of the arrays had one or more two-item couplings, many had two or more such groupings each involving two to five specimens. The frequency of arrays according to the number of couplings and the number of items in them is given in Table III.

An alteration of this table to give the number of arrays having only one, or two couplings, and so forth, regardless of the number of items coupled gives Table IX.

To summarize the coupling behavior. Couplings were found in seventy form and fifty saint arrays. While this is respectively 71.5 percent and 54.3 percent of all arrays, of the

TABLE VIII

FREQUENCY OF ARRAYS BY NUMBER AND MEMBERSHIP OF COUPLINGS

Arrays Classified by Frequency and Membership of Couplings	Forms		Saints	
1 coupling of 2 specimens	18	25.7%	13	26.0%
2 couplings of 2 specimens each	7	10.0	5	10.0
3 couplings of 2 specimens each	6	8.6	2	4.0
4 couplings of 2 specimens each	2	2.9		
5 couplings of 2 specimens each	1	1.4		
1 coupling of 3 specimens	4	5.7	4	8.0
2 couplings of 3 specimens each	1	1.4	3	6.0
3 couplings of 3 specimens each				
1 coupling of 4 specimens	1	1.4	3	6.0
2 couplings of 4 specimens each	1	1.4		
1 coupling of 5 specimens	1	1.4		
1 coupling of 6 specimens	1	1.4		
2 or 3 couplings of 2, 3, 4, or 5 specimens in each	27	38.6%	19	38.0
Total	70	100.0%	50	100.0%

TABLE IX

FREQUENCY OF ARRAYS BY NUMBER OF COUPLINGS ONLY

Arrays Classified by Frequency of Couplings only	Forms		Saints	
1 coupling only	25	35.7%	20	40.0%
2 couplings	20	28.6	16	32.0
3 couplings	22	31.4	14	28.0
4 couplings	2	2.9		
5 couplings	1	1.4		
Total	70	100.0%	50	100.0%

variable spaced arrays these comprise 85.4 percent and 76.9 percent respectively. The arrays of both sets were about equally divided into arrays of one, two, or three couplings only and the majority of couplings had only two or three specimens thus grouped. Specimens close to the 'best liked' or first place item were more often involved in couplings than in other positions.

SPECIMEN ISOLATION

Though, as we found, many specimens in the arrays were grouped into couplings or placed in ties, a large number of them were located independently of others and in isolation.

For the form arrangements, we find that the eighty-two

subjects adopting a variable spacing placed 330 items out of a total of 820, or 40.5 percent, in isolated positions. For the saint arrays, of the 650 specimens disposed by the subjects in variably spaced arrangements, 197 specimens, or 30.5 percent, were placed singly. More saint specimens, therefore, than forms were placed either in ties or coupled in groups.

Conclusions

1. The majority of the subjects availed themselves of the opportunity afforded them of spacing the specimens at distances to represent their relative preferences. For both sets of material, geometrical forms and simple compositions, more than three-quarters of the arrays showed this manner of disposition.

2. The subjects also utilized the opportunity to group items together to show their identity in preference, as in ties, or in general similarity, as in couplings.

3. While the arraying behavior with both sets of specimens was alike in general, some differences existed between them in the frequency of occurrence of different types of arrays, and in the tieing and coupling behavior.

Significance

From the extent to which differential spacing of items and grouping was resorted to by the subjects we can conclude that with relatively simple material, such as the geometrical forms and compositions used in the experiments, most subjects are capable of rendering more discriminative preference judgments than simple ranking. The method appears to allow greater freedom of expression and, assuming that the spacing and grouping were not purely capricious, indicates that more information can be gained about preferences than simple ranking affords.

Our interest here lies in the individual array as an expression of the subject's reactions to the specimens. If we accept as one of the problems of experimental esthetics the disclosing of the criteria involved in preference judgments and their inter-action in particular situations, one of our primary con-

cerns must be to develop methods of capturing as fine expressions of preference as the subject is capable of expressing.

A group order could be secured from these spaced arrays. One way would be to give each array, no matter how long, an arbitrary value of one hundred or ten, determine the relative values by this scale of the positions of the specimens, and average them. Or a set length on a table could be set for every subject, the best liked and least liked specimens being always at given positions.

We have gone into the details of the grouping behavior in the belief that with more experimentation we may be able to learn significant things about the subject's reactions to the material from this behavior. We found differences in the ways in which the subjects reacted to the two sets of material. The saint arrays, for example, had more regularly spaced arrays and had more specimens involved in ties and couplings than did the forms. It might be concluded from this that the subjects were less able to discriminate between these specimens, for various reasons, than between the forms. Some subjects, six in number, refused to attempt to arrange the saint compositions on the grounds that they all 'looked alike' and there was nothing to choose between them. It seems legitimate to conclude that an array having many specimens disposed in ties and in couplings indicates that that subject did not have the bases for judgments, found less to choose between different specimens, and hence, defined by behavior, was less 'sensitive' than one whose array of the same material had no or few tied specimens and in which most specimens were independently placed or in a few couplings. It seems likely that when we arrive at a stage of greater knowledge about the factors involved in judgments that such arraying behavior will be informative.

A survey of the preference orders did not reveal more agreement between subjects than is shown in experiments with rank order. Since it seems likely that more freedom was given to the subject than other methods allow and hence a clearer picture should result of his preferences, this lack of agreement apparently is the result of our failure to see it, through a lack

of knowledge of the criteria operating. The next step would thus seem to be an analysis of the factors involved in preference judgments for many types of esthetic material and objects, and for objective techniques of determining the subtleties and finer gradations of preferences.

(Manuscript received May 8, 1939)

REFERENCE

1. THURSTONE, L. L., A law of comparative judgment, *Psychol. Rev.*, 1927, 34, 273–286.

STUDIES IN THERMAL SENSITIVITY: 13. EFFECTS OF STIMULUS-TEMPERATURE IN SERIATIM COLD-MAPPING

BY WILLIAM LEROY JENKINS

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In the preceding study,[1] it was shown that the intensity of cold experienced from a given temperature depends primarily upon the sensitivity of the stimulated area and not upon the stimulus-size as such. The traditional 'cold spot' doctrine was found inadequate to explain the results, and a new *concentration theory* was proposed. In terms of this theory, sensitivity is a function of the concentration of relatively minute receptors; specifically, it is proportional to the square root of the number of receptors per unit area.

The question naturally arises: Can this theory be extended to cover the effects of stimulus-temperature as well as those of stimulus-size? An answer to this question can be approached by obtaining comparative seriatim scores with a standard stimulator size at different temperatures.

Procedure

The seriatim mapping was carried out in substantially the same manner as in the previous study.[2] One member of each group acted as experimenter; the other two alternated as subject and recorder. At each experimental period a checkerboard of 3 × 3 mm squares was mapped 12 times, alternately with a standard and a comparison temperature. The standard of 17° C. was compared with 8°, 11°, 20°, 23° and 26° C., and the standard of 23° C. with 20°, 26°, 27½° and 29° C.—all temperatures being measured at the inlet. The mapping followed an approximately random sequence, as previously described.

Subjects reported 0 for neutral, 1 for weak, 2 for medium and 3 for strong cold. The *score* for each square was determined by adding up the 6 numbers reported. The empirical justification for treating these ordinal numbers as if they were cardinal has been discussed in the previous article.[3] Correlations between scores at standard and comparison temperatures were computed by the product-moment formula.

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[1] Jenkins, W. L., Studies in thermal sensitivity: 12. Part-whole relations in seriatim cold-mapping, *J. exper. Psychol.*, 1939, **25**, 373–384.

[2] *Op. cit.*

[3] *Op. cit.*

Results

The upper part of Table 1 shows the correlations obtained for all subjects. At temperatures of 23° and lower, ap-

TABLE 1

Correlations

All Subjects

Temp. ° C.	.00 .59	.60 .64	.65 .69	.70 .74	.75 .79	.80 .84	.85 .89	.90 .94	.95 1.00	Total Cases	Med. Corr.
17/8	1	2	–	5	4	3	3	2	–	20	.77
17/11	4	1	2	1	2	4	3	3	–	20	.80
*17/17	4	–	1	5	8	14	5	2	1	40	.81
17/20	4	–	1	5	3	2	2	1	–	18	.74
17/23	2	1	3	3	1	6	5	1	–	22	.81
17/26	4	2	3	2	–	1	4	–	–	16	.68
23/20	3	–	1	2	1	2	4	1	–	14	.80
23/26	1	1	1	4	4	2	–	1	–	14	.75
23/27½	10	1	2	3	2	1	–	–	–	19	.60
23/29	14	6	6	2	2	–	–	–	–	30	.60

Selected Subjects

Temp. ° C.	.00 .59	.60 .64	.65 .69	.70 .74	.75 .79	.80 .84	.85 .89	.90 .94	.95 1.00	Total Cases	Med. Corr.
17/8	–	1	–	2	3	3	2	2	–	13	.81
17/11	–	–	1	–	1	3	3	3	–	11	.86
*17/17	2	–	–	2	4	8	4	1	1	22	.82
17/20	–	–	–	–	1	1	2	1	–	5	.87
17/23	1	–	–	–	1	4	4	1	–	11	.84
17/26	2	1	2	1	–	1	3	–	–	10	.70
23/20	–	–	–	1	–	1	4	1	–	7	.86
23/26	–	–	1	3	3	2	–	1	–	10	.77
23/27½	3	–	2	3	2	1	–	–	–	11	.71
23/29	5	6	2	2	1	–	–	–	–	16	.63

* Preliminary check on reliability, performed on the first day, without previous training.

proximately half were .80 or better, which accords with the results of the preceding study.[4] At 26°, 27½° and 29°, however, there was a progressive reduction until at 29° C. no subject attained a correlation as high as .80.[5] To minimize the

[4] *Op. cit.*

[5] Most of the scores at 29° C. were so low as to fall below the level of accurate discrimination, even for subjects who showed excellent consistency at lower temperatures. It is significant, however, that two subjects with relatively high average scores gave odd-even correlations of .85 and .92 in the 29° reports, although the correlations of 29° with 23° scores were below .80. This indicates that the behavior of the scores themselves may become irregular as the limen is approached.

effects of random reporting, a group of the better subjects was selected on the basis of their general consistency at lower temperatures, and only their results used in the later computations. The correlations for these selected subjects are shown in the lower part of Table 1.

As a preliminary step, *average scores* were computed for each stimulus-temperature. In Fig. 1, the large chart shows the mean scores for all subjects combined; the small charts give similar results for the individual subjects. Each dot in the latter represents the mean score from a map of 50 squares. Only two temperatures could be used at each weekly meeting and a new map had to be stamped on the skin each time. In spite of the fact that the data were thus collected over a period of five weeks, there is a surprising amount of consistency shown in the average scores on the majority of the charts.

A comparison of the large chart with the small ones shows that the form of the combined curve is a compromise obtained by adding a number of variant forms. Yet the general shape of this curve is reproduced in the majority of the charts (*i.e.*, A, C, D, F, G, I, J, L, N, S, T, W). The variants range from a horizontal line with no clear evidence of a break (K), through descending curves (B, M, Q, R) to sloping lines (E, H). A few cases (O, P, U, V) are too irregular for interpretation. Considering only the most typical form, it appears that in these subjects temperature changes below 23° C. have little or no effect on average scores.

If we now plot *individual* scores at standard temperatures against those at comparison temperatures, the graphs shown in Fig. 2 are obtained. Here the data for all 23 selected subjects have been combined in order to secure evidence on the general effects of temperature at various score levels. The ordinates represent scores at standard temperatures, grouped into 7 divisions for clarity. The abscissæ represent scores at comparison temperatures. The circles show median comparison scores corresponding to the seven standard score levels. Roughly, these charts show what might be expected from the average score curves. Below 23° C., the circles are close to

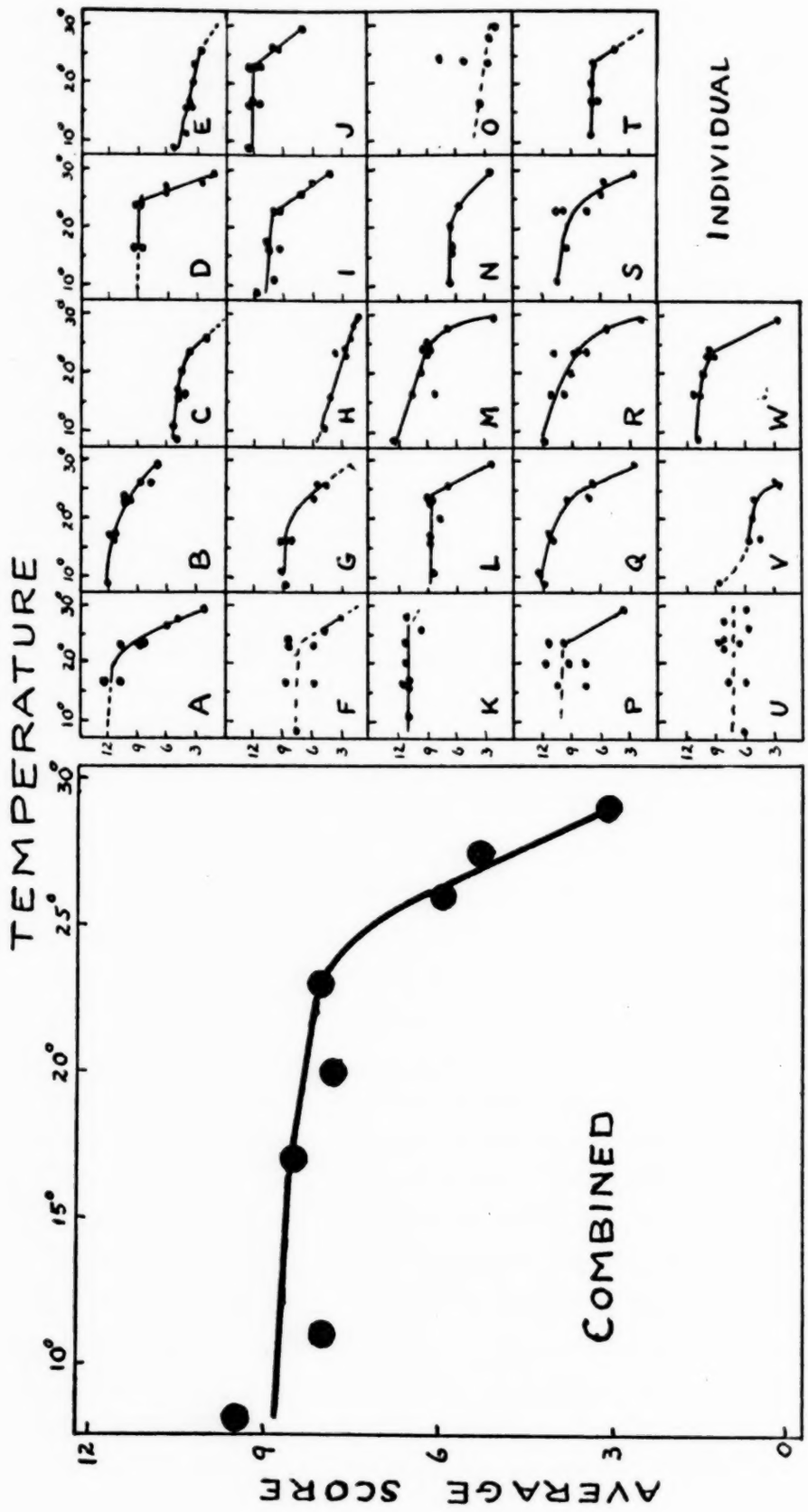

FIG. 1. Relation of average scores to stimulus-temperatures.

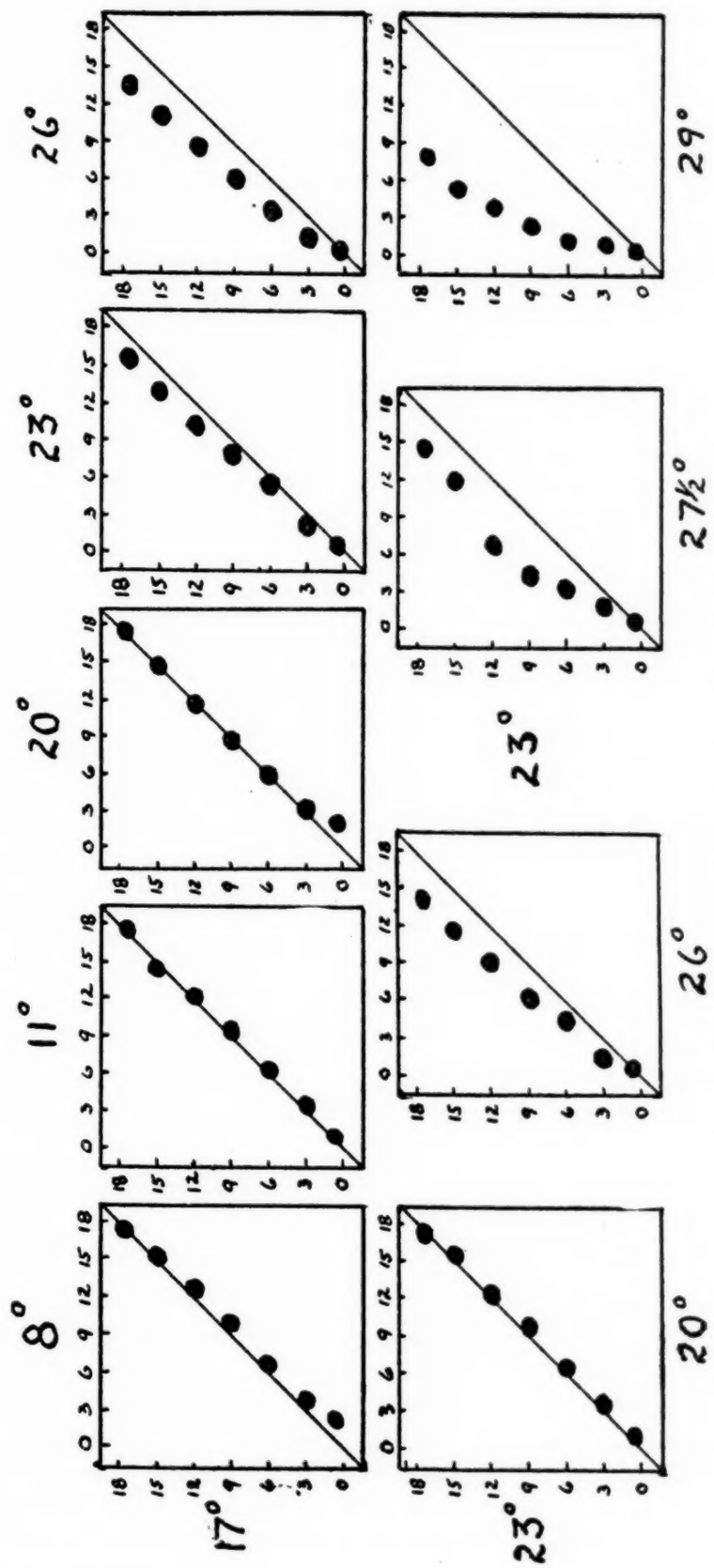

FIG. 2. Median comparison scores for 7 standard score levels.

the diagonal. At 26°, 27½° and 29° C., there is progressive divergence.[6]

A closer inspection, however, shows that the divergence from the diagonal is *relatively* greater at the lower score-levels. To investigate this relation more exactly, the *percentages* of change were computed with the 17° scores as 100, making the necessary adjustments where the actual standard was 23° C. These percentages are shown graphically in Fig. 3. They

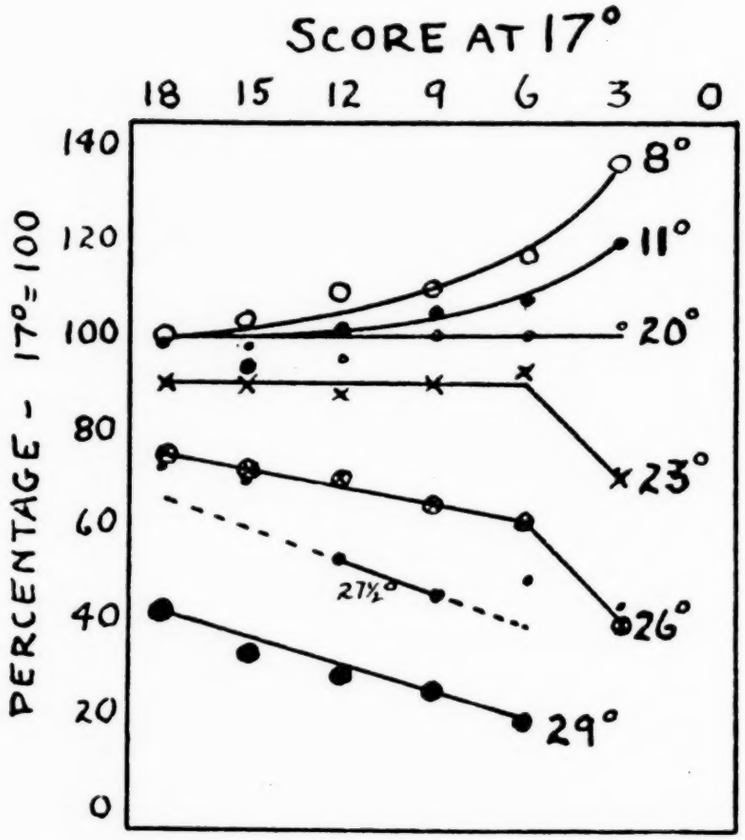

FIG. 3. Percentage changes with temperature for 7 standard score levels.

follow a systematic distribution which can be expressed in the following generalization: *Both above and below 17° C., the percentage change with temperature is progressively greater at the lower score levels.*

[6] Likewise, similar charts for the individual subjects follow what might be expected from the individual charts of average scores. If the average score increases below 23° C., the medians show a corresponding divergence to the right. If the average score is relatively unchanged at lower temperatures, the medians are close to the diagonal.

These curves are based on the combined data of 23 subjects, neglecting possible individual differences. It is safe to say, however, that the principle applies at least to the majority of the subjects. Detailed examination of the individual scattergraphs fails to disclose a single clear-cut exception.

Discussion

On the basis of the foregoing results, three new hypotheses can be proposed:

1. *Individual Cold Receptors Are All-or-none in their Response.*—The evidence for this is Fig. 1. Many of the individual charts show approximately a horizontal line between 8° and 23°, meaning that the average score is unchanged through this range. It follows that the individual receptors in these subjects must obey the same law; *i.e.*, they must be unaffected by supra-liminal temperature changes.

It is unimportant whether the receptor action rises instantly, or merely very rapidly, to the full peak. Likewise, it is evident that the peak might vary from time to time as the result of adaptation or other changes. The major point is that once this peak is reached, the activity is unaffected by further temperature change, and is all-or-none in this sense.

2. *The Concentration Theory can be Extended to Cover the Effects of Temperature.*—When a lower temperature causes a more intense experience it does so merely by adding to the concentration of active receptors. This follows automatically if we assume that cold receptors are all-or-none in all subjects. The various curves in Fig. 1 then become dependent upon the distribution of temperature limens.[7]

3. *The Distribution of Temperature Limens among Receptors Is not Random.*—If the distribution were purely random, a change of temperature should cause the addition or subtraction of the same percentage of active receptors at all score-levels. The lines of Fig. 3 would then be parallel to the horizontal axis. However, the lines fan out to the right,

[7] It is possible to assume that cold receptors are all-or-none in some subjects and not in others. In the absence of direct evidence, parsimony dictates the assumption of the simpler hypothesis: the same kind in all individuals.

indicating that temperature changes cause progressively greater percentage changes in score at the lower score-levels. In terms of the concentration theory, this means that the distribution of temperature limens is different in low-score and high-score regions. In low-score regions there are relatively more unresponsive receptors (*i.e.*, those that respond only to low temperatures). In high-score regions, there are relatively more highly-responsive receptors. This is significant, because it suggests that the distribution of *strength* (*i.e.*, frequency of nerve impulses transmitted) may not be random among receptors, but may follow an analogous plan. That is, high-score regions may contain relatively more strong and highly-responsive receptors; low-score regions relatively more weak and unresponsive receptors. *Concentration* and *strength* would then work hand-in-hand.

If the distribution of strength among receptors is purely random, there is only one variable to determine sensitivity: *number*. Because of the square-root function, the number of receptors would have to be very large. For example, a sensitivity range from 1 to 10 would require receptor concentrations from 1 to 100. (Even with fairly small stimulators, it seems probable that we can establish close to 10 score-levels in a single map that are reliably different statistically.) On the other hand, with *two* variables—number and strength—all of the gradations could be accounted for in terms of a much smaller number of receptors. Sensitivity would be proportional, not to the square root of the number of receptors, but to the square root of some more fundamental neurological units, probably nerve impulse frequency. The greater flexibility of this revised hypothesis recommends it for provisional adoption.

Summary

An investigation of comparative seriatim scores at different stimulus-temperatures leads to the formulation of three hypotheses:

1. *Cold Receptors Are All-or-none in their Response.*—Average scores in many subjects show no change between 23° and 8°; consequently the individual receptors (in these

subjects, at least) must be unaffected by supra-liminal changes of stimulus-temperature.

2. *The Concentration Theory can be Extended to Cover the Effects of Stimulus-Temperature.*—When a lower temperature causes a more intense experience, it does so merely by adding to the concentration of active receptors. This follows automatically unless it is assumed that cold receptors are all-or-none in some subjects and obey a different principle in others.

3. *The Distribution of Limens among Receptors Is not Random.*—Low scores show greater percentage changes with temperature than high scores. Therefore, there must be relatively more poorly-responsive receptors in low-score regions; relatively more highly-responsive receptors in high-score regions. This suggests that the distribution of *strength* among receptors may also not be random, but that there may be relatively more strong receptors in high-score regions; relatively more weak receptors in low-score regions. Concentration and strength would then work hand-in-hand. In this more flexible interpretation of the concentration theory, sensitivity would be determined by the square root of the concentration of some fundamental neurological units (such as nerve impulse frequency), and the number of receptors required would be greatly reduced.

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INFLUENCE OF TYPE FORM ON EYE MOVEMENTS *

BY MILES A. TINKER AND DONALD G. PATERSON

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In 1928, the writers published reading speed data for text set in lower case and for text set in all capitals.[1] The results showed that lower case text was read 13.4 percent faster than text set in all capital letters.[2] In our discussion of this finding, we suggested that the number of fixational pauses is increased in reading the all capitals text and further that this was probably due to the less characteristic word forms inherent in material printed in all capitals.

It is obvious that reading performance tests can only show differences in speed of reading without providing an analytical picture of the eye movements involved. The writers, therefore, have completed an eye-movement study designed to reveal the specific patterns of eye movements responsible for the disclosed differences.

Each of 22 college students read 10 paragraphs from the Chapman-Cook Speed of Reading Test, Form A, set in lower case and 10 different paragraphs from Form B of the same test set in all capitals before the Minnesota Eye-Movement Camera.[3] The photographic records yielded the following five analytical measures: number of fixations, number of words per fixation, duration of pauses, perception time and number of regressions.

The results are presented in Table I. For each measure

* The writers are grateful to the University of Minnesota Graduate School for research grant to finance this study.

[1] M. A. Tinker and D. G. Paterson, Influence of type form on speed of reading, *J. appl. Psychol.*, 1928, **12**, 359–368.

[2] For methodology in our typographical studies see M. A. Tinker and D. G. Paterson, Studies of typographical factors influencing speed of reading, XIII. Methodological considerations, *J. appl. Psychol.*, 1936, **20**, 132–145.

[3] M. A. Tinker, Apparatus for recording eye movements, *Amer. J. Psychol.*, 1931, **43**, 115–118.

the mean for the 22 subjects reading 10 paragraphs (300 words) is given for each type form. For example, the means of the data for lower case are as follows: (*a*) number of fixations was 195.2, (*b*) number of words perceived per fixational pause (words per fixation) was 1.6; (*c*) duration per fixational pause (pause duration) was 0.23 second; (*d*) perception time (total of pause durations) was 45.4 seconds; and (*e*) number of regressions for the 10 paragraphs (regression frequency) was 31.1. . Corresponding data are given for reading the text set in all capitals.

Examination of the table reveals that the reading of all capitals resulted in a 12.4 percent increase in the number of fixations and a 12.5 percent decrease in the number of words per fixation. It is to be noted that these percentages correspond rather closely to the differential reading rate established in our 1928 reading performance experiment mentioned above. Thus the eye-movement technique substantiates our original surmise that absence of characteristic word forms in the all capitals material as compared with lower case text is responsible for the speed of reading difference. This conclusion is also supported by evidence from another analytical study,[4] using the distance method of measuring perceptibility, which revealed *less prominent* word forms in all capitals than in lower case text.

Inspection of the data dealing with pause duration and perception time indicates that our subjects actually spent less time per fixation in reading the all capitals text (8.6 percent differential). When the combined effect of fixation frequency and pause duration is observed in the perception time measure, however, we note that our readers spent 7.1 percent more time in perceiving the all capitals text.

There is no difference between the two type forms so far as the regression frequency measure is concerned.

The results for each of the 22 subjects show a striking agreement with the trends in the group data of Table I. Twenty-one readers employed more fixations on the all

[4] M. A. Tinker, The influence of form of type on the perception of words, *J. appl. Psychol.*, 1932, **16**, 167–174.

TABLE I

MEAN EYE-MOVEMENT MEASURES FOR 22 COLLEGE SUBJECTS READING SET IN TEXT LOWER CASE AND IN ALL CAPITALS*

Note: Pause duration and perception time are reported in seconds.

Type Form	Fixation Frequency	Words per Fixation	Pause Duration	Perception Time	Regression Frequency
Lower Case.....	195.2	1.6	0.23	45.4	31.1
All Capitals.....	229.4	1.4	0.21	48.6	31.2
Differences.....	+34.2	−0.2	−0.02	+3.2	+0.1
Percent Diff.....	+12.4	−12.5	−8.57	+7.1	+0.3

* Ten paragraphs from the Chapman-Cook Speed of Reading Test, Form A, were set in lower case and 10 paragraphs from Form B of the same test were set in all capitals. All paragraphs were printed as follows: Scotch Roman, 10 point, 19 pica line width, set solid on egg-shell paper stock.

capitals than on the lower case text while one subject used the same fixation frequency on both texts. Likewise, twenty-one subjects read the all capitals text with fewer words per fixation and one subject read both texts with an equal number. Twenty-one readers had briefer pause durations on the all capitals text and only one had a longer duration. In a similar manner, 18 subjects employed longer and four subjects shorter perception time on the text in all capitals. As might be expected from the group trend, which revealed no difference between type forms in regression frequency, there is little consistency for direction of differences between all capitals and lower case in this measure. Twelve subjects exhibited fewer regressions on the all capitals text, nine more regressions and one subject the same number.

We interpret the findings to mean that, due to word form differences, the reading of all capitals text necessitates more fixations with fewer words perceived per fixation and in spite of less time devoted to each pause, the total perception time is increased. These four measures reflect the difficulty our readers encountered in reading the all capitals text. Even so, it is apparent that the sequence of fixations is as regular in reading all capitals as in reading lower case. In other words the all capitals text does not disorganize nor upset the customary patterns of eye movements along the line of print except for a closer spacing of the fixations.

The writers believe that the performance reading test administered under natural reading conditions is the soundest technique for determining the extent to which any two typographical arrangements differ in their effects on speed of reading. Such performance tests, however, give little or no information in regard to the oculo-motor mechanics involved in the differences. Eye-movement measures, therefore, are essential for a qualitative analysis permitting insight with reference to the nature of the difficulties present in one arrangement as compared with another. Thus a scientific typography requires both approaches, one which yields measures of amount, the other giving a description of what is happening.

Summary and Conclusions

1. In 1928 the writers demonstrated a 13.4 percent advantage for lower case type compared with material set in all capitals so far as speed of reading is concerned.

2. Eye-movement photographs of a new group of twenty-two subjects show that this advantage is based primarily upon the necessity for increasing the number of fixations when reading all capitals with a corresponding decrease in the number of words per fixation.

3. Although the duration per fixation is reduced in reading all capitals, nevertheless, total perception time is increased.

4. The difficulties encountered in reading all capitals do not upset the customary pattern of fixation sequences since the number of regressions is equal in reading both type forms.

5. The writers believe that performance tests and eye-movement studies are complementary methods of investigation needed in the development of a scientific typography. Performance tests measure the degree to which any particular typographical arrangement differs from another in its effect on speed of reading. Eye-movement photography yields a description of the oculo-motor behavior underlying the disclosed differences.

(Manuscript received May 13, 1939)

NEW ERGOGRAPH FOR ARM AND FINGER ERGOGRAMS

BY J. T. GOBEY

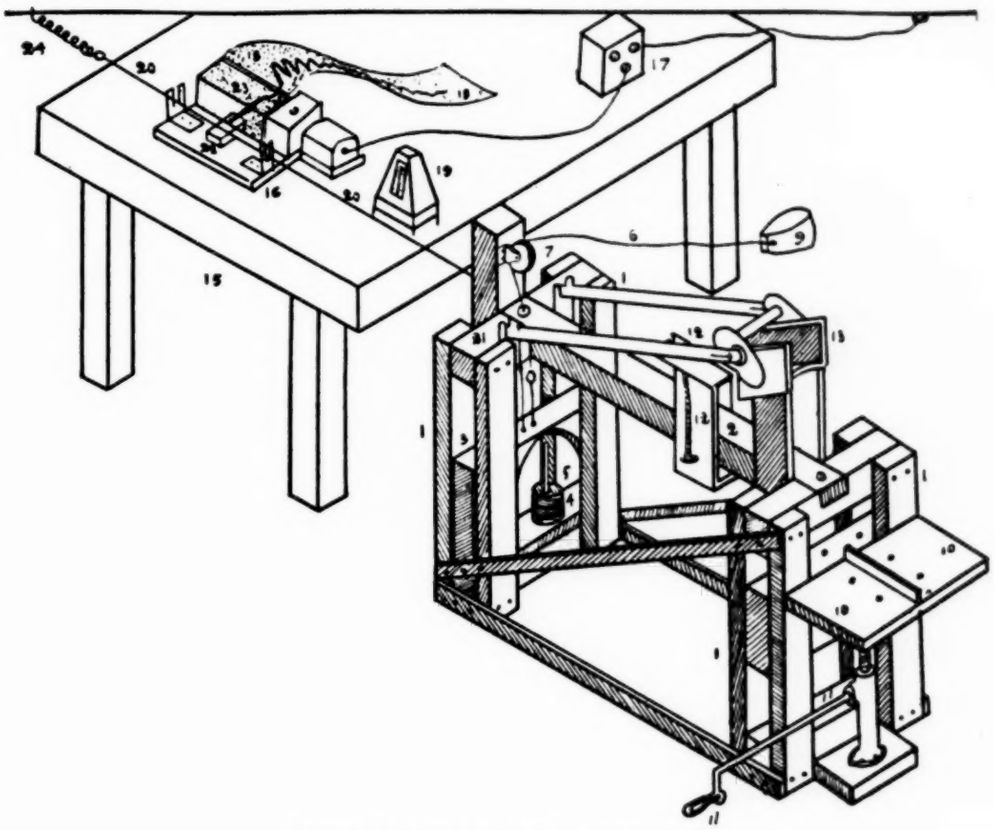
University of Pennsylvania

In order to carry out a research project dealing with the similarity of the ergograms taken on arm and finger, an ergograph has been constructed by John R. Roberts of the University of Pennsylvania with the advice of Prof. G. R. Wendt. An isometric drawing of the apparatus is reproduced to accompany this note. The ergograph consisted of two upright wooden frames (1) approximately 87 cms high and 56 cms wide each, joined together by a heavy middle and four side rails (2). Inside the first frame was another moveable frame (3) about 30 cms high, with an iron rod (4) at the center of its lower bar to hold the weights (5) to be lifted by the subject. By means of a chain (6) passing from this moveable frame over the pulley (7) at the top of the vertical bar (8), the weights were connected with the leather strap (9) applied either around the subject's wrist or to the first joint of the middle finger, as the case might be. Any contraction of the muscles of the arm or of the finger, therefore resulted in motion of the weighted frame.

On the second upright frame, and built into the apparatus, there was an adjustable double stool (10) where the subject was seated. By means of a leaver (11) the stool could be raised or lowered to suit the convenience of the subject.

The two other important parts of the apparatus were attached to the upper horizontal bar (2) joining the two outside frames—these were (*a*) a support for the hand (12) when ergograms of the middle fingers were taken, and (*b*) a support for the arm (13) when arm and finger records were produced. Either part was adjustable. In order to eliminate other than arm or middle finger muscles from participating in lifting the weights, the member of the body engaged in work was strapped (14) to its support on the ergograph.

On a separate table (15) in front of the above described



Isometric drawing of the apparatus.

apparatus, there were installed a kymograph (16) built by J. R. Roberts to permit the use of rolls of wax paper 20 cms in width, a rheostat (17) for regulating the speed with which the paper (18) was moving through the kymograph, and a metronome (19) to ensure regularity of performance of the work.

In order to record the subject's work a durable cord (20) was stretched from the weight on the ergograph over a pulley underneath the upper horizontal bar (21) in front of it to the carriage (22) on the kymograph to which a stylus (23) was attached. Fastened to this carriage, the same cord was connected with a coil spring (24) at the other end of the room, exerting uniform tension on it. Thus, whenever the arm or the middle finger contracted, the displacement of the weight released the tension exerted on the cord connecting the apparatus with the kymograph, the coil spring immediately caused the carriage to move with the stylus, and the latter scratched a record of the displacement of the weight on the wax paper.

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